

RCUK CCSCN meeting

Ceramic membranes for energy applications and CO₂ capture

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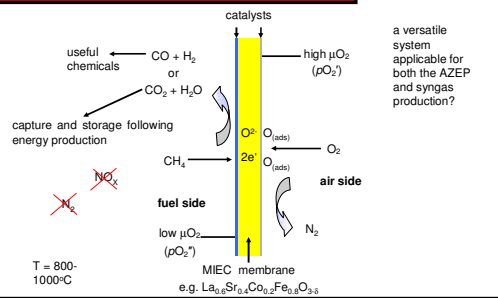


November 4th 2009, Royal Academy of Engineering

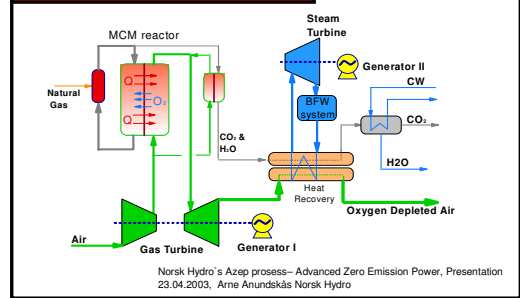
Introduction

- > Membrane-based oxyfuel combustion with CO₂ capture
- > How does the membrane work – ion and mixed ion and electron conductors
- > Other interesting membrane processes – hydrogen production
- > Chemical looping combustion and hydrogen production

Application: methane utilisation

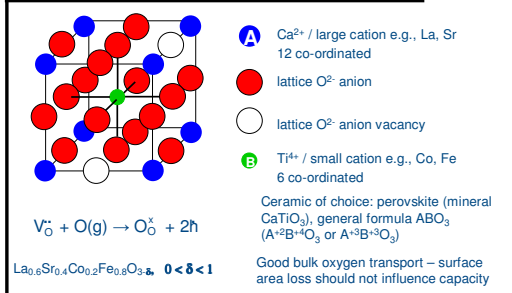


Combustion with CO₂ capture

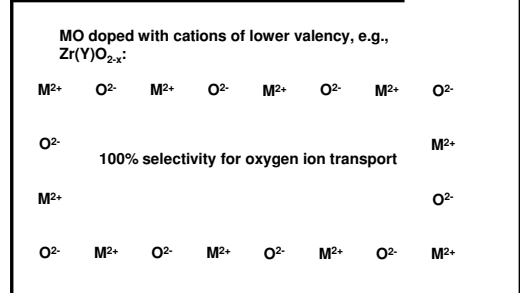


Norsk Hydro's Asep process – Advanced Zero Emission Power, Presentation 23.04.2003, Arne Anundskås Norsk Hydro

Oxygen storage / release

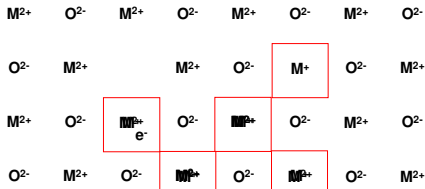


Ionic conductors: mechanism of conduction



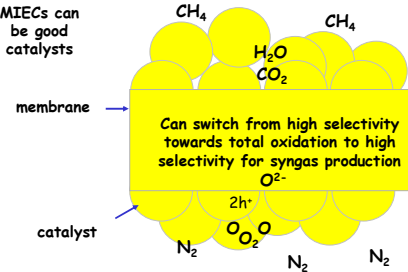
Mixed ionic and electronic conductors

MO doped with a second cation exhibiting two oxidation states e.g. LaMnO_{3-x}

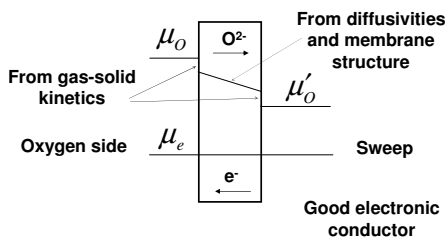


MIEC for methane oxidation and CO_2 capture

MIECs can be good catalysts



Membrane thermodynamics: MIECs

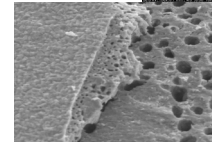
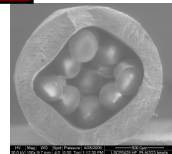


MIECs fabrication and microstructure

Thursfield, A., Metcalfe, I.S., 'Methane oxidation in a mixed ionic-electronic conducting ceramic hollow fibre reactor module', *J. Solid State Electrochem.* **10** (2006) 604-616.

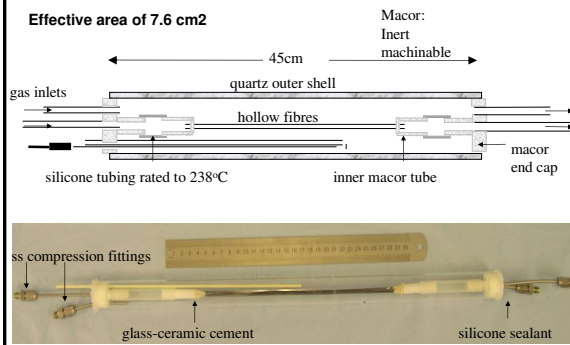
Thursfield, A., Metcalfe, I.S., 'Air separation using a catalytically modified mixed conducting ceramic hollow fibre membrane module', *J. Membrane Sci.* **288** (2007) 175-187.

Membrane fabricated by Professor Kang Li of Imperial College

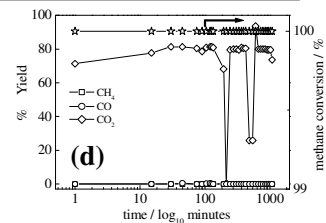


Hollow fibre reactor module

Effective area of 7.6 cm²

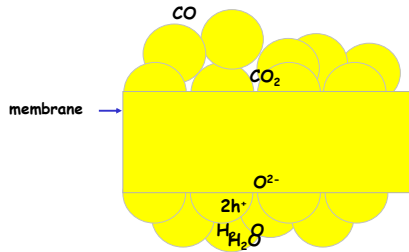


Results from module – methane oxidation



Yield of gaseous carbon-containing species. 2.2% methane in helium supplied at 50 ml/min (0.81 $\mu\text{mol/s}$). 40 ml/min of 21% oxygen (6.21 $\mu\text{mol/s}$). Co-current operation at 858°C.

Hydrogen production from water vapour

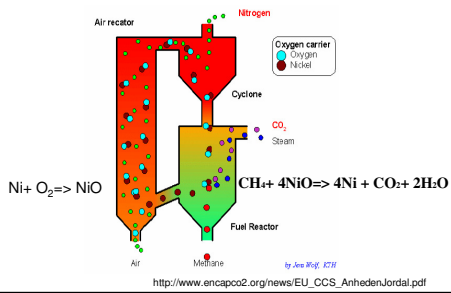


Chemical looping processes

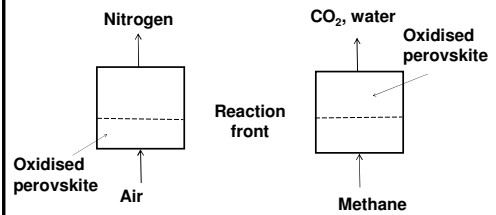
But you can perform the same chemistry and use the same modelling approach for periodic reactor operation

Chemical looping

Chemical looping processes



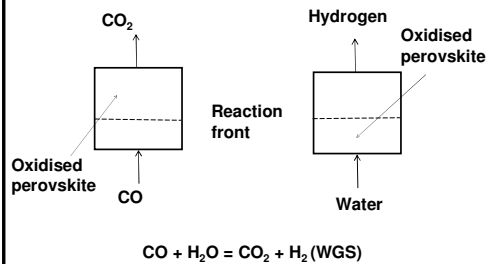
Chemical looping processes



Chemical looping processes

- > New materials for chemical looping processes
- > Advantages of non-stoichiometric oxides for looping
 - avoid phase changes, active with low surface areas
- > Hydrogen production from looping
- > perovskite versus supported NiO
- > Use temperature programmed techniques for quick screening
- > Stability over a number of cycles
- > Hydrogen purity
- > Only chemical, no mechanical stability work, fixed bed with periodic operation

Chemical looping processes for hydrogen



Summary

- Membrane-based oxyfuel combustion with CO₂ capture
- How does the membrane work – ion and mixed ion and electron conductors
- Some results from a membrane module
- Other interesting membrane processes – hydrogen production
- Chemical looping combustion and hydrogen production

Acknowledgements

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EPSRC