RCUK CCSCN meeting

Ceramic membranes for energy applications and CO_2 capture

Alan Thursfield,[1] Ian S. Metcalfe[1] & Kang Li[2]

Newcastle University[1]

Imperial College[2]

Newcastle University

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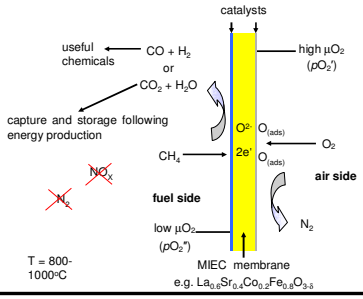
Introduction

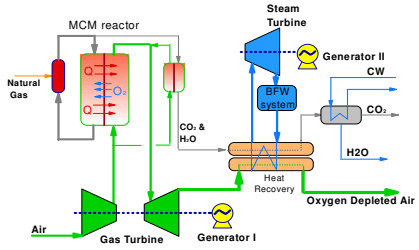
- **Membrane-based oxyfuel combustion with CO_2 capture**
- **How does the membrane work – ion and mixed ion and electron conductors**
- **Other interesting membrane processes – hydrogen production**
- **Chemical looping combustion and hydrogen production**

Application: methane utilisation



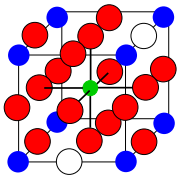
a versatile system applicable for both the AZEP and syngas production?

Combustion with CO2 capture



Norsk Hydro´s Azep prosess– Advanced Zero Emission Power, Presentation 23.04.2003, Arne Anundskås Norsk Hydro

Oxygen storage / release



A Ca^{2+} / large cation e.g., La, Sr 12 co-ordinated

lattice O^{2-} anion

lattice O^{2-} anion vacancy

B Ti^{4+} / small cation e.g., Co, Fe 6 co-ordinated

Ceramic of choice: perovskite (mineral $CaTiO_3$), general formula ABO_3 ($A^{+2}B^{+4}O_3$ or $A^{+3}B^{+3}O_3$)

$V_O^{\bullet\bullet} + O(g) \rightarrow O_O^X + 2\hbar$

$La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$, $0 < \delta < 1$

Good bulk oxygen transport – surface area loss should not influence capacity

Ionic conductors: mechanism of conduction

MO doped with cations of lower valency, e.g., $Zr(Y)O_{2-x}$:

M^{2+} O^{2-} M^{2+} O^{2-} M^{2+} O^{2-} M^{2+} O^{2-}

O^{2-} M^{2+}

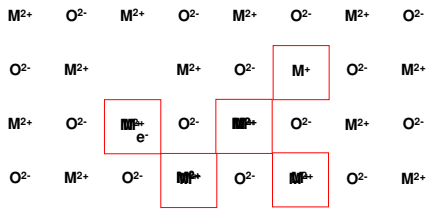
100% selectivity for oxygen ion transport

M^{2+} O^{2-}

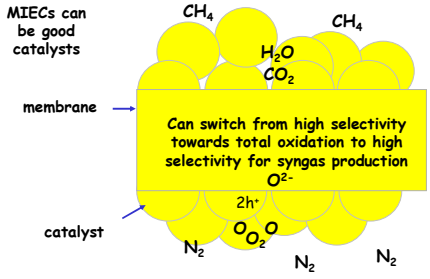
O^{2-} M^{2+} O^{2-} M^{2+} O^{2-} M^{2+} O^{2-} M^{2+}

Mixed ionic and electronic conductors

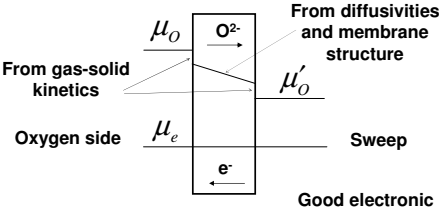
MO doped with a second cation exhibiting two oxidation states e.g. $LaMnO_{3-x}$



MIEC for methane oxidation and CO_2 capture



Membrane thermodynamics: MIECs

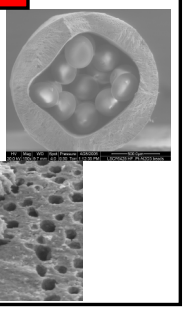


MIECs fabrication and microstructure

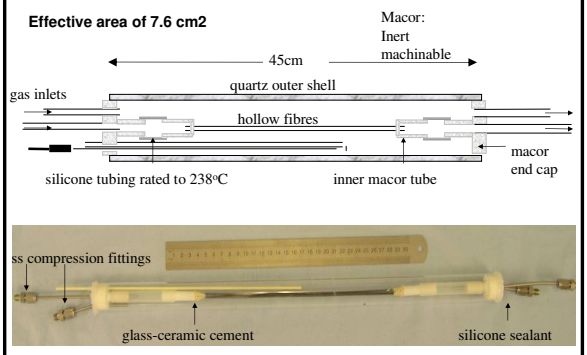
Thursfield, A., Metcalfe, I.S., 'Methane oxidation in a mixed ionic-electronic conducting ceramic hollow fibre reactor module', J. Solid State Electrochem. 10 (2006) 604-616.

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.

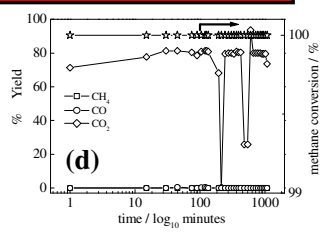
Membrane fabricated by Professor Kang Li of Imperial College



Hollow fibre reactor module

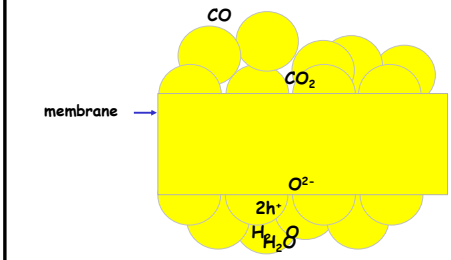


Results from module – methane oxidation



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

Hydrogen production from water vapour

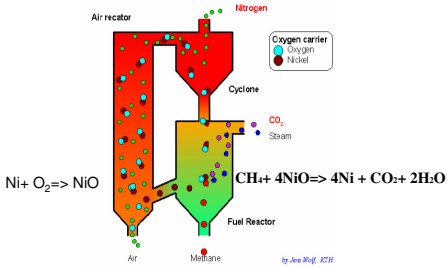


Chemical looping processes

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

Chemical looping

Chemical looping processes

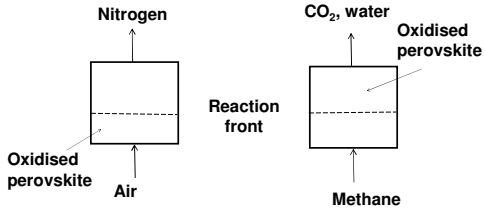


Ni+ O_2=> NiO

CH_4+ 4NiO=> 4Ni + CO_2+ $2H_2O$

http://www.encapco2.org/news/EU_CCS_AnhedenJordal.pdf

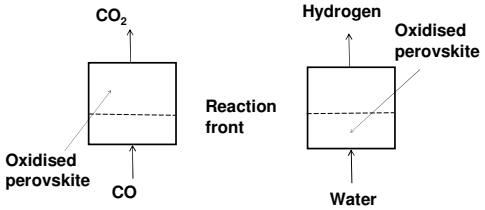
Chemical looping processes



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



$CO + H_2O = CO_2 + H_2$ (WGS)

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