Centre for CO_2 Technology

UCL

Using Computational Multiphysics to Optimise Channel Design for a Novel PEM Fuel Cell Stack

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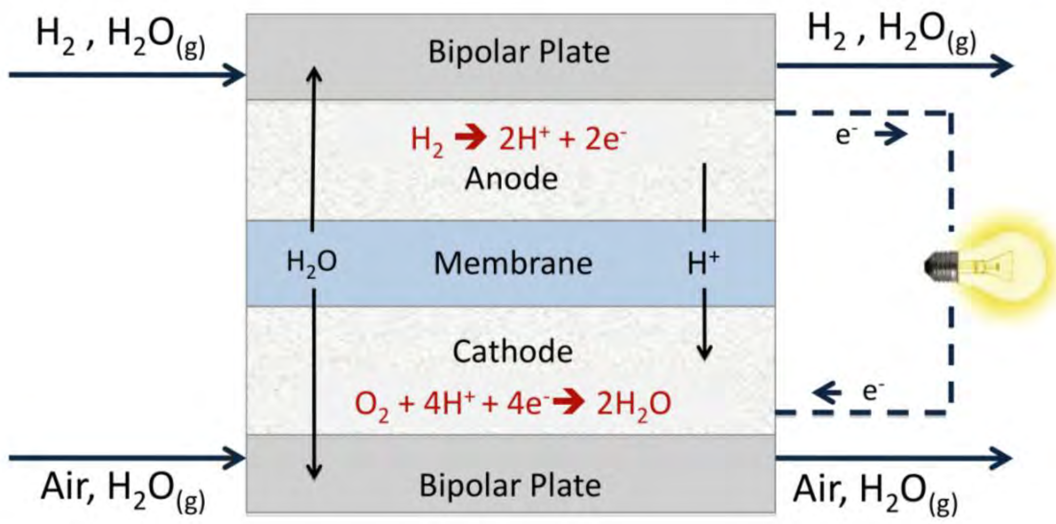
Carbon Management • Power Systems • Sustainability

Overview

- Introduction
- Modelling Objectives
- Model Domain
- Model Solution
- Results
- Conclusions

Introduction

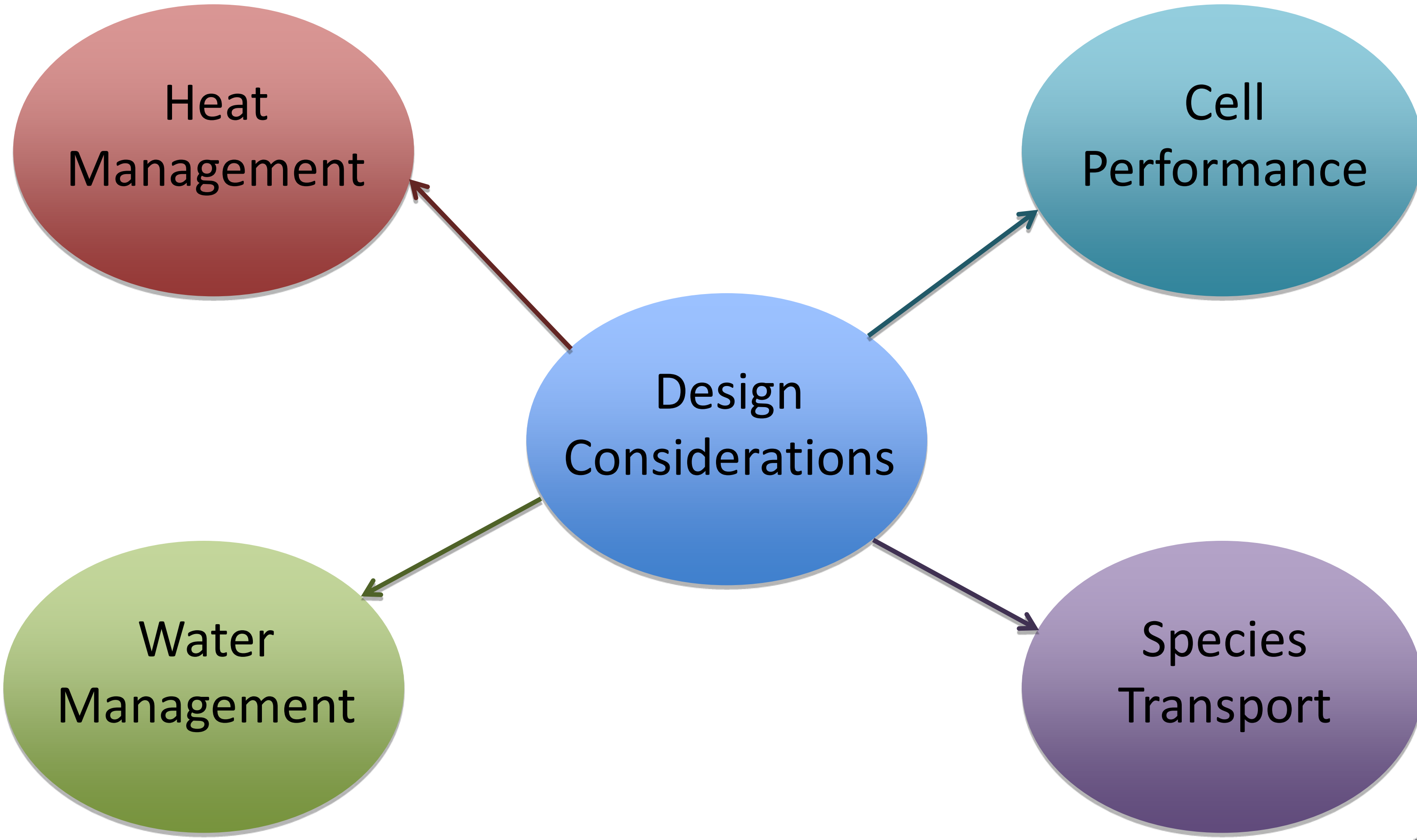
A PEM fuel cell is an electrochemical engine:



The bipolar plate/current collector has several key functions:

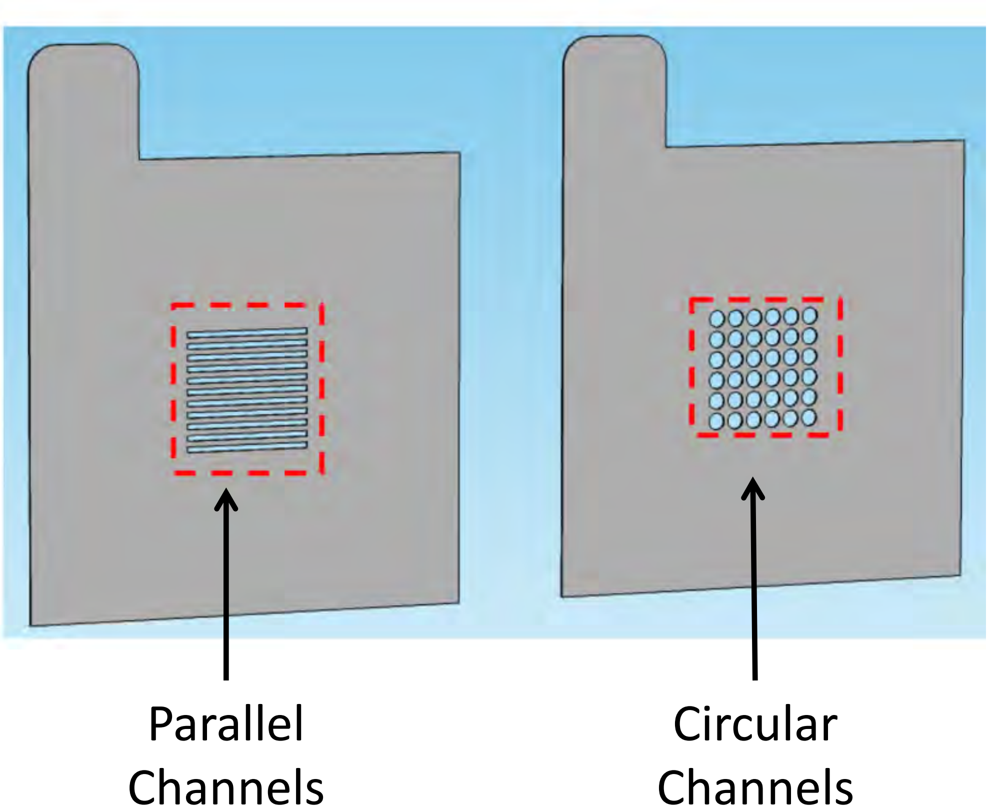
- To distribute gas flows
- To allow current conduction
- To provide structural stability

Modelling Objectives

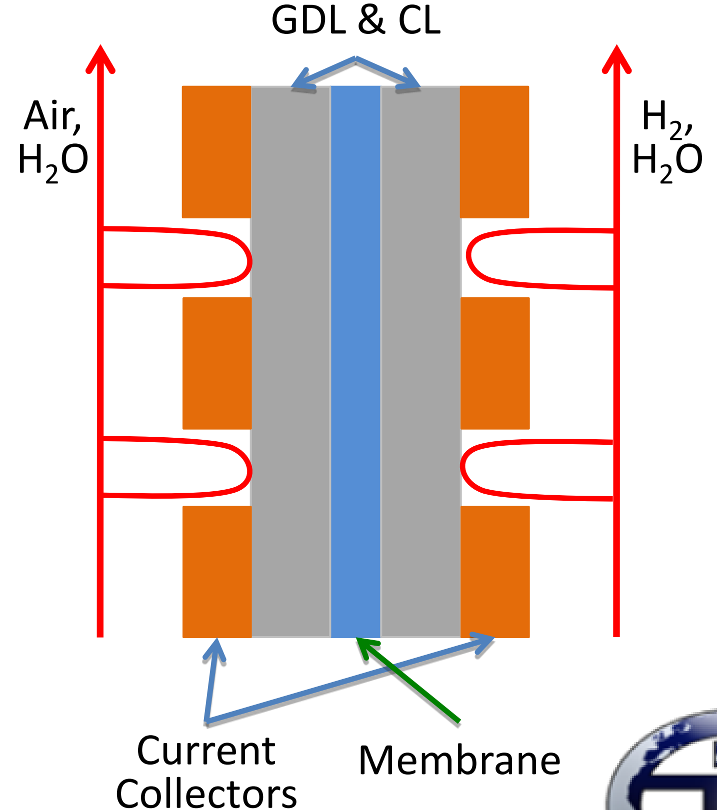


Model Domain

3D model of a 5 cm^2 PEM fuel cell using printed circuit board current collectors with two different flow channel designs:



Cross section of 3D model:



Model Solution

Cell operation determined by:

- Weakly Compressible Navier-Stokes → Pressure, ***p***, Velocity, ***u***
- Maxwell-Stefan Diffusion → Mass fractions, $\boldsymbol{w_i}$
- Butler Volmer & Tafel equations → Current, ***i***
- Heat Conduction & Convection → Temperature, ***T***
- Schögl equation → Velocity of water, $\boldsymbol{u_w}$

Operation at 353 K and 1 atm

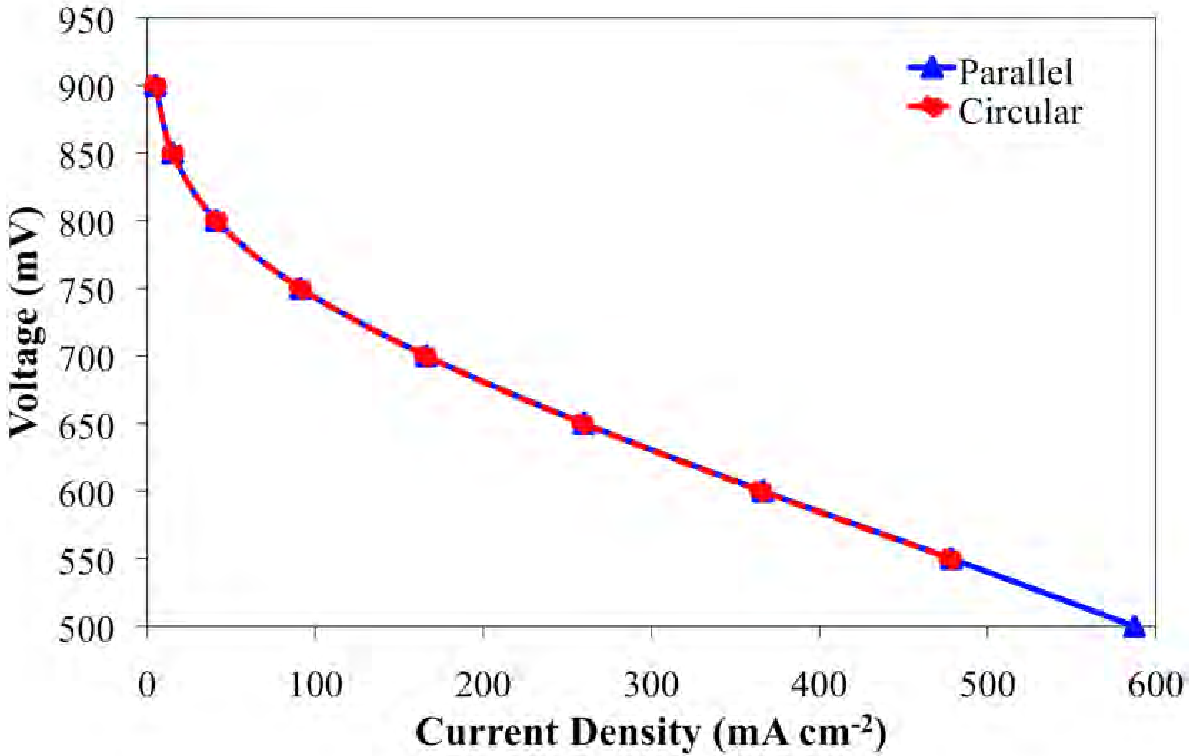
COMSOL Multiphysics 4.2 used to solve models

Structured mesh for each design, approx. 318000 degrees of freedom

Parametric, segregated solution procedure using MUMPS solver

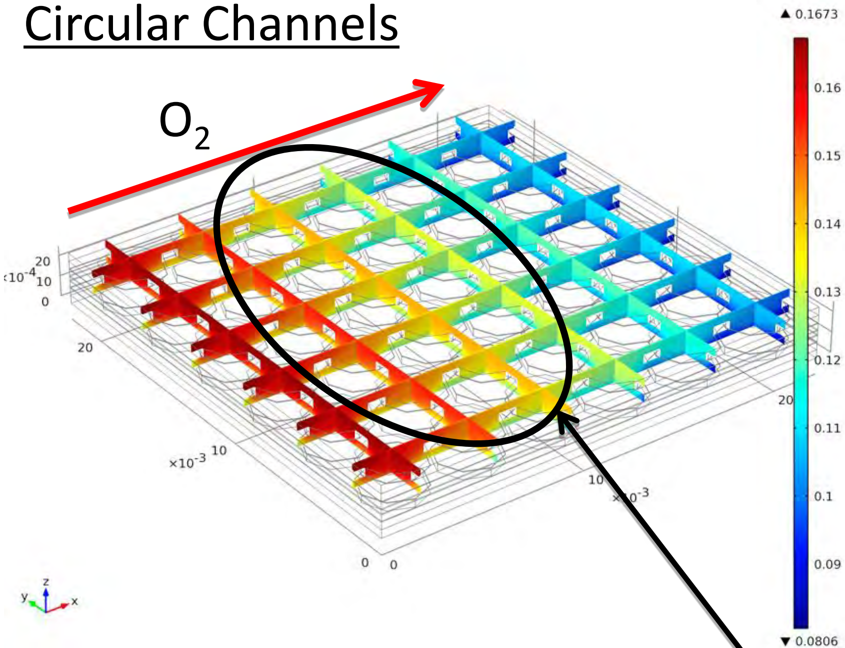
Comparison of Polarisation Curves

- Both the circular and parallel designs have similar VI curves
- Significant activation losses between 0 to 100 mA cm^{-2}, ~150 mV loss
- Cannot deduce best design from VI curves alone

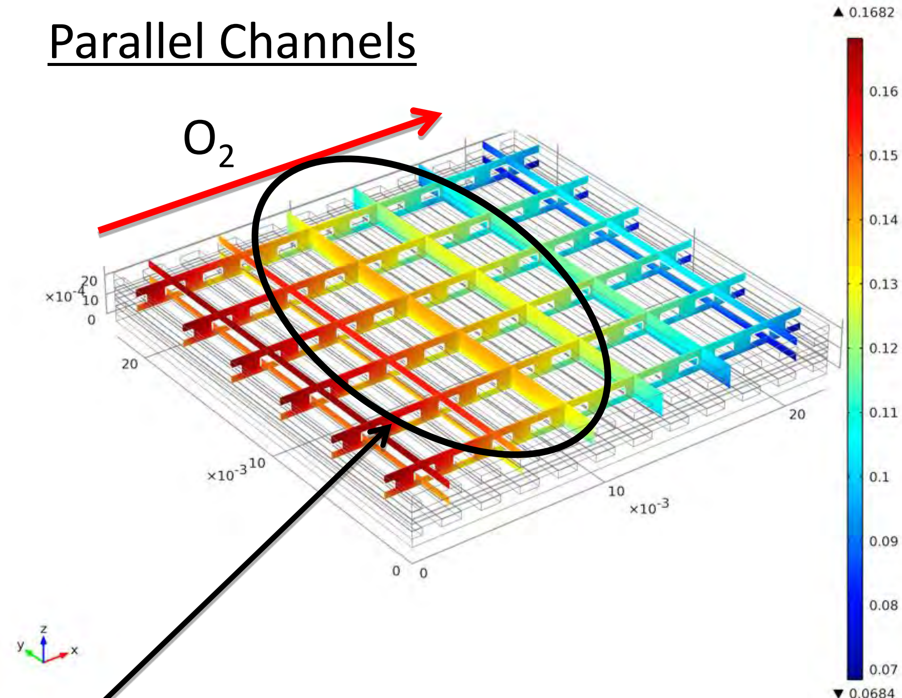


Mass fraction of O_2 at 0.6V

Circular Channels



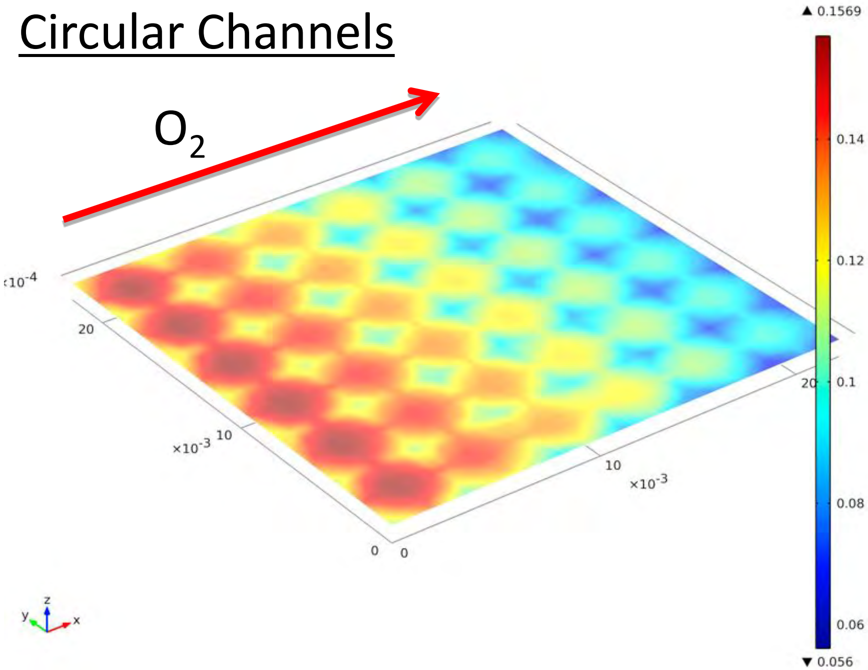
Parallel Channels



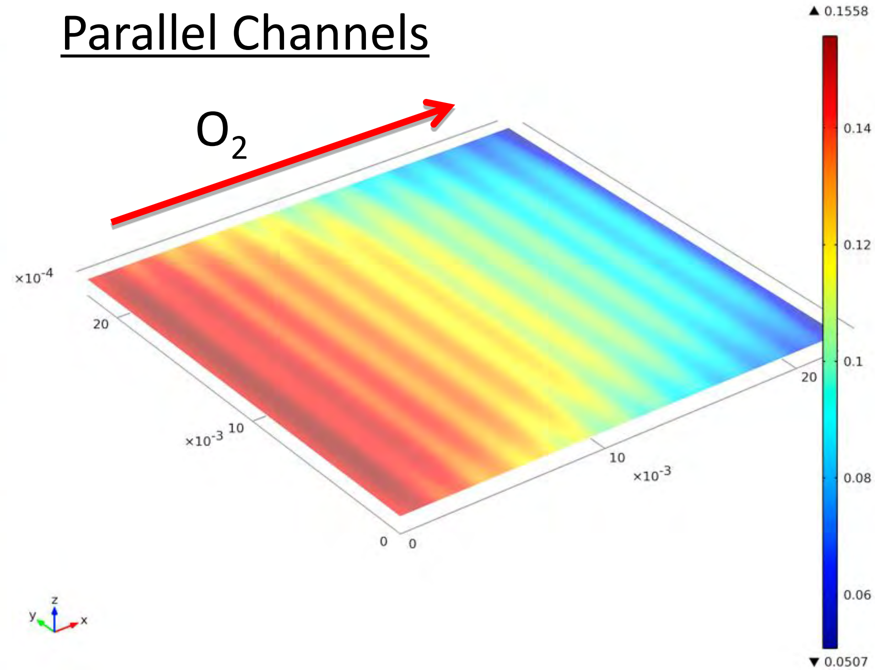
Greater depletion of O_2 earlier in cell with circular channels compared to parallel channels

Mass fraction of O_2 at membrane - catalyst interface at 0.6 V

Circular Channels



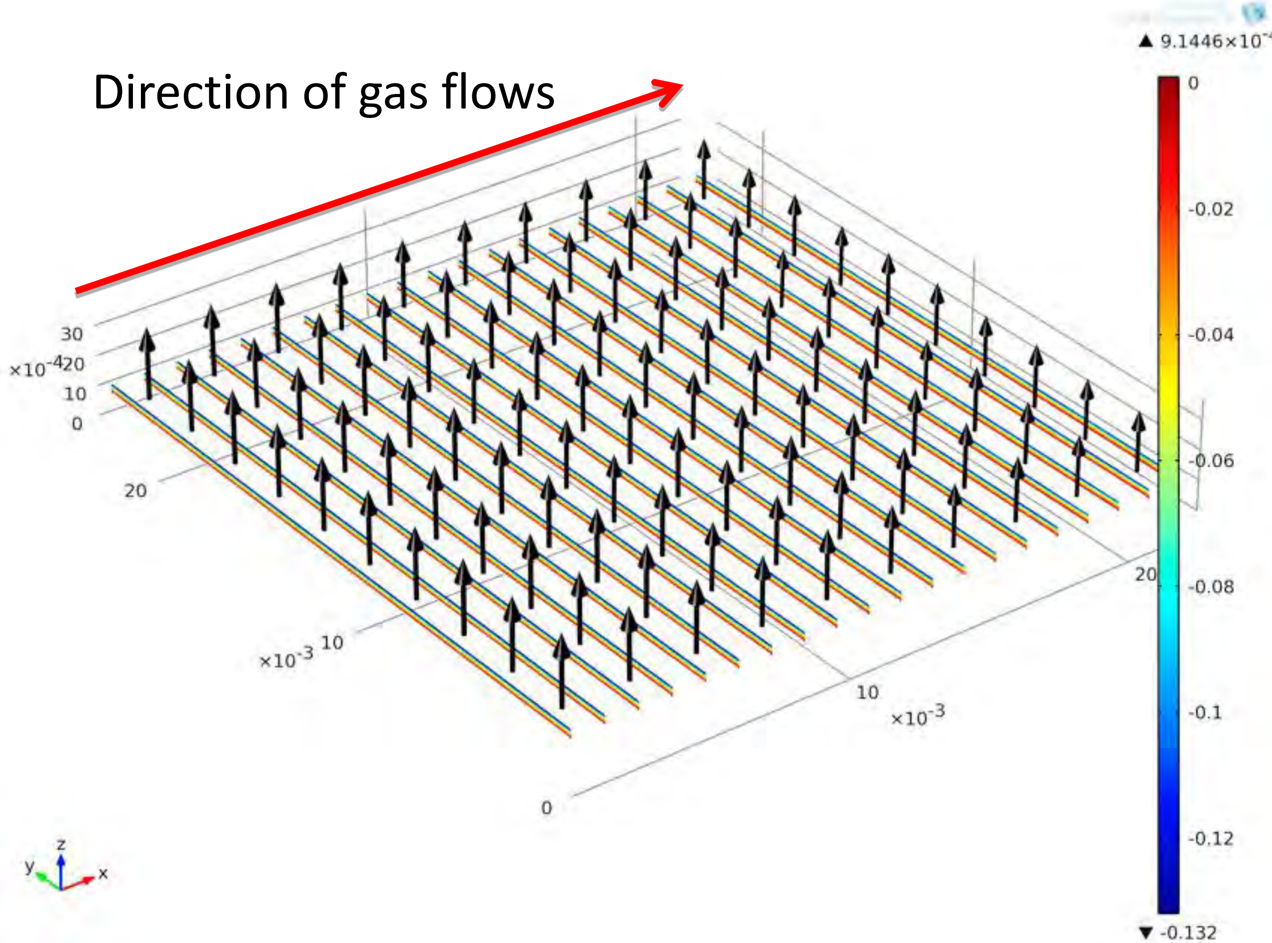
Parallel Channels



- Oxygen consumption governed by channel design
- Highest consumption under the ribs of the plate
- More uniform distribution of reactants when using parallel channels

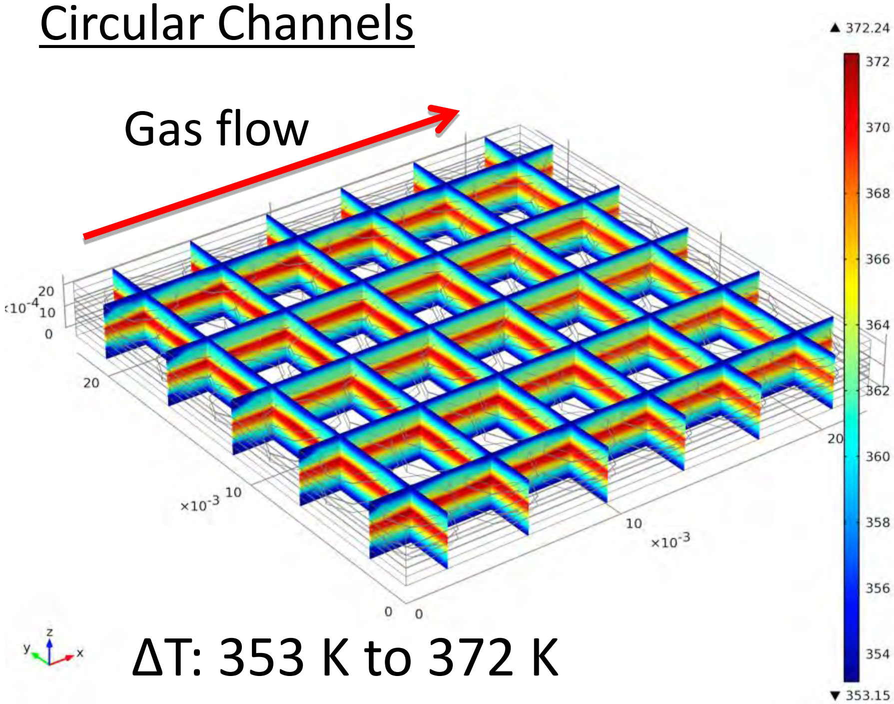
Water flux across the membrane at 0.6V

- Movement of water from anode to cathode side
- Electroosmotic drag is greater than the pressure term
- Flooding could be a potential problem
- Parallel channels are preferable due to uniform distribution



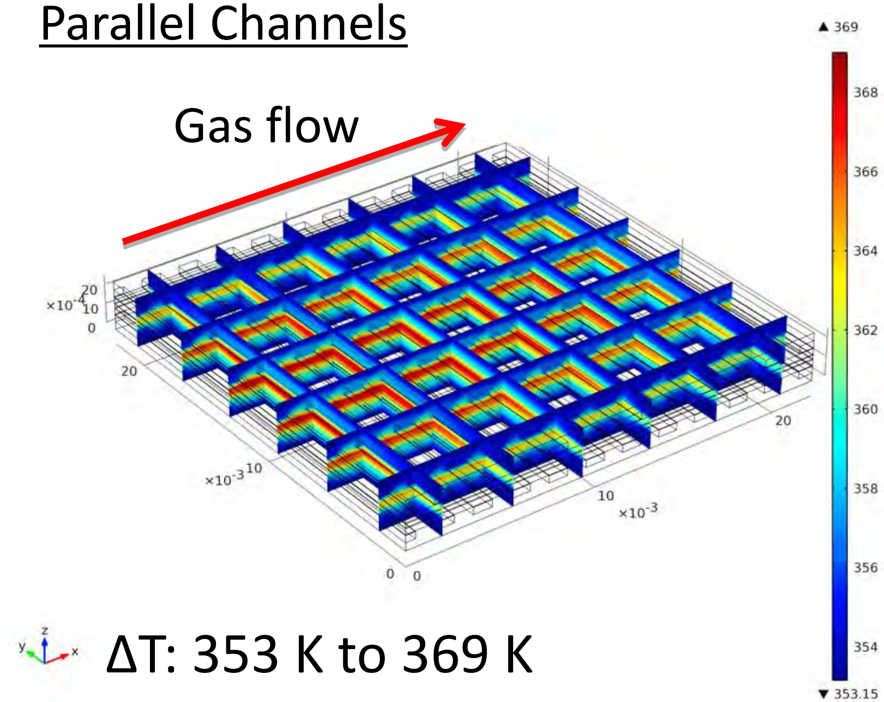
Temperature Profile at 0.6V

Circular Channels



ΔT: 353 K to 372 K

Parallel Channels



ΔT: 353 K to 369 K

- Changes in temperature due to electrochemical reactions and resistive heating
- Larger proportion of cell operates at higher temperatures when using circular channels

Conclusions

Circular Channels

- Reactant depletion earlier in the cell
- Operating temperature: 353K – 372K
- Potential flooding issue

Parallel Channels

- Uniform distribution of reactants
- Operating temperature: 353K – 369K
- A smaller proportion operates at higher temperatures
- Less potential for flooding

Verdict:

Parallel channel bipolar plate most suitable of the two designs!

Thank you!

For further information, please email at flora.daniels.09@ucl.ac.uk