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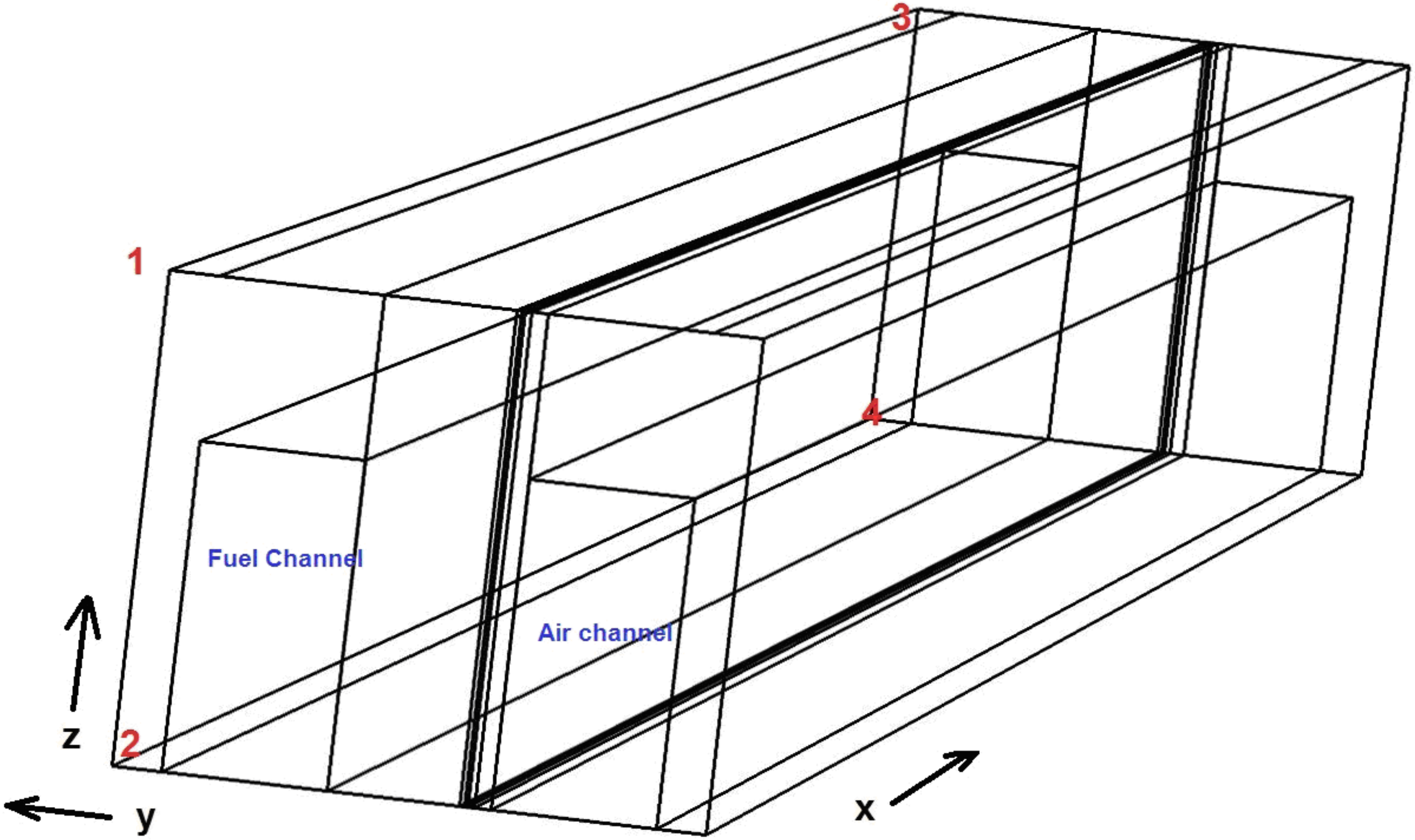
Solid Oxide Fuel Cell Material Structure Grading in the Direction Normal to the Electrode/Electrolyte Interface using COMSOL Multiphysics

Martin Andersson, Bengt Sundén, **Department of Energy Sciences, Lund University**

Mathematical Model - Geometry



Mathematical Model

- Momentum transport
  - Continuous equation for the porous material and electrodes
- Mass transport [O_2/N_2 + $H_2/H_2O(CH_4/CO/CO_2)$]
  - Maxwell-Stefan equation, incl. Knudsen diffusion
- Heat transport
  - LTE approach
    - » Conductivity in solid phase
    - » Conductivity and convection in gas phase

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Mathematical Model

- Assumptions:
  - 3D
  - Fuel utilization: 80 %
  - Cell voltage: 0.7 V
  - Co-flow
  - Inlet temperature: 1000 K
  - Fuel: 30 % pre-reformed natural gas

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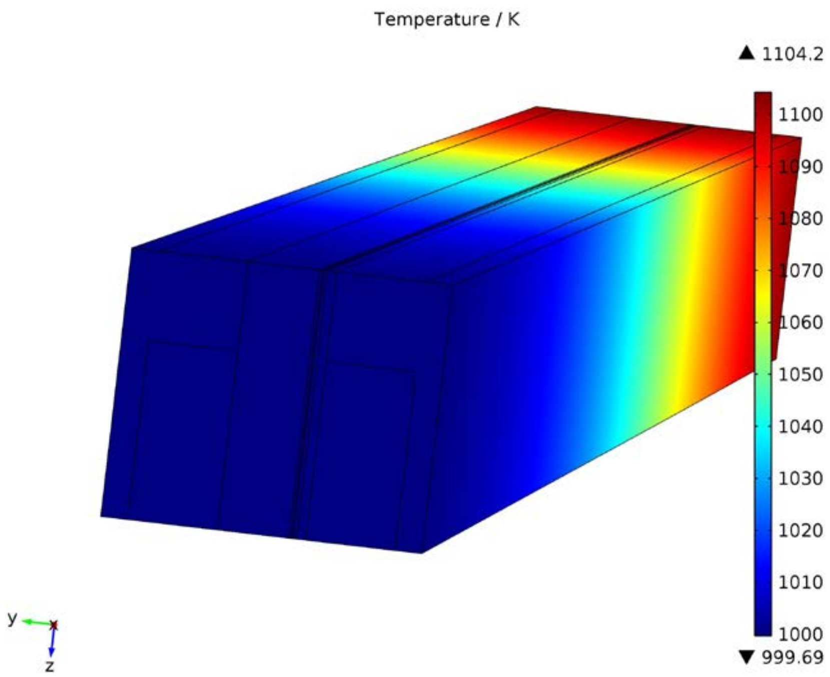
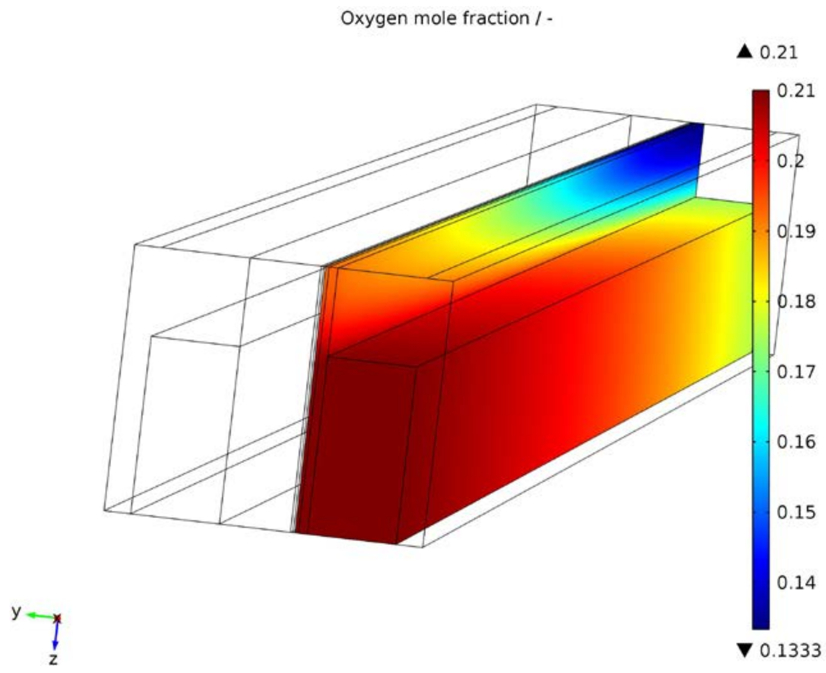
Results – Standard case





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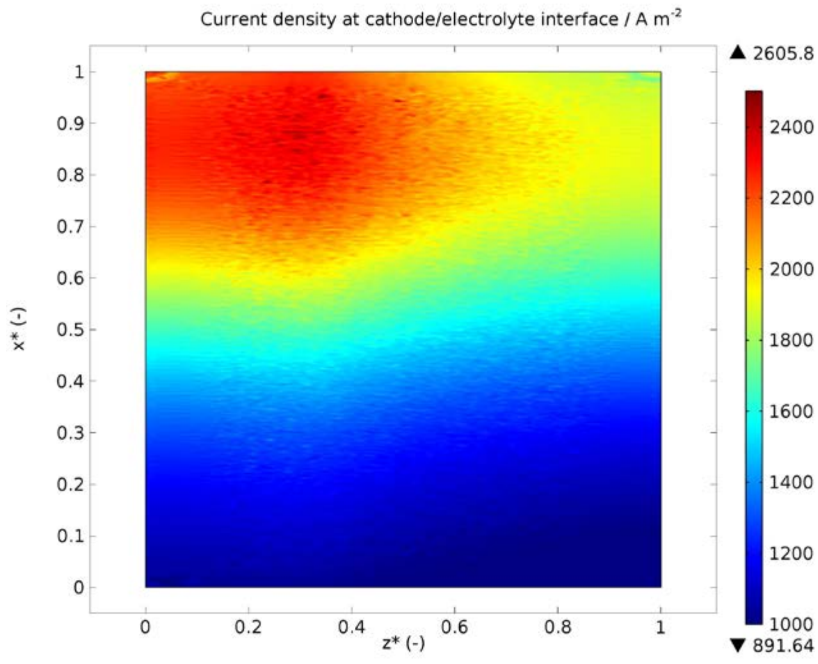

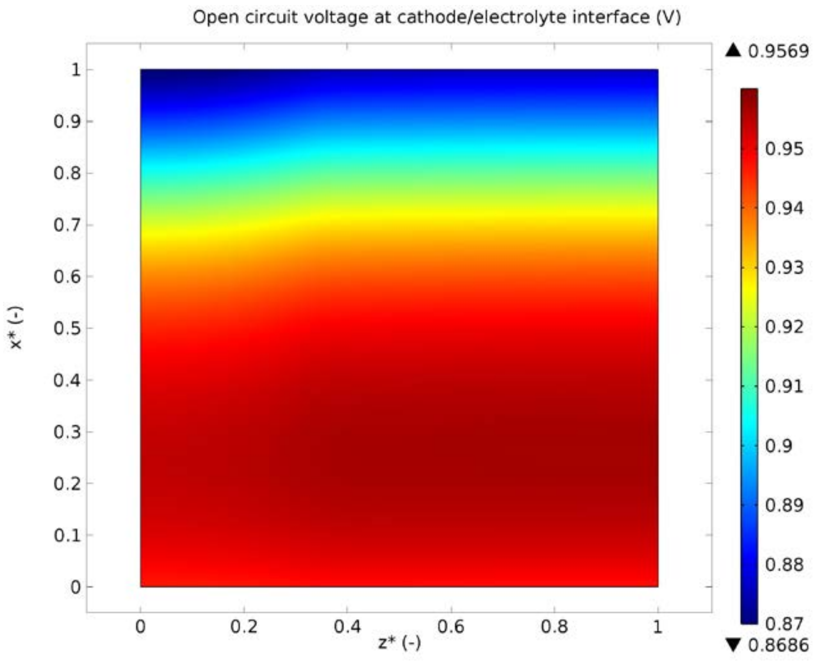

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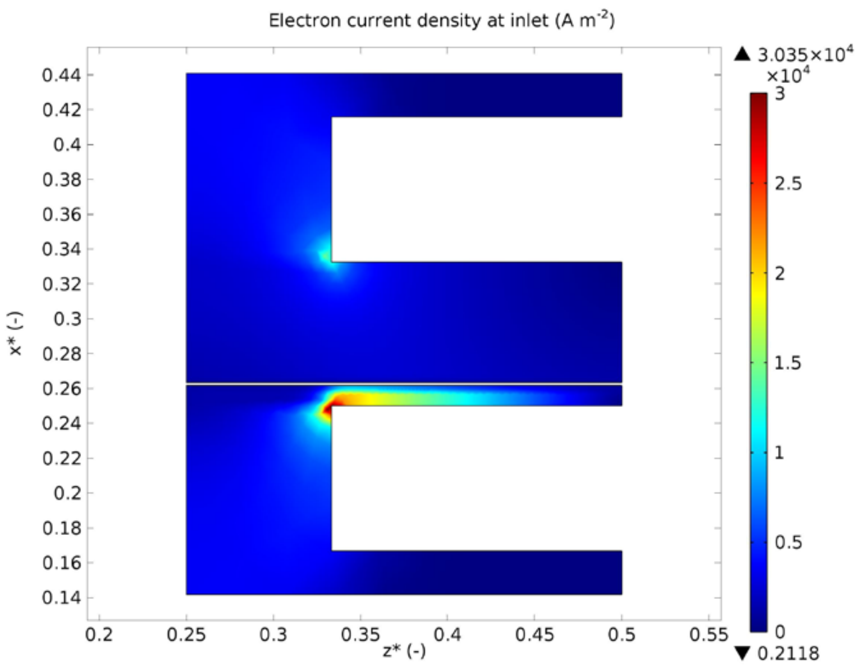

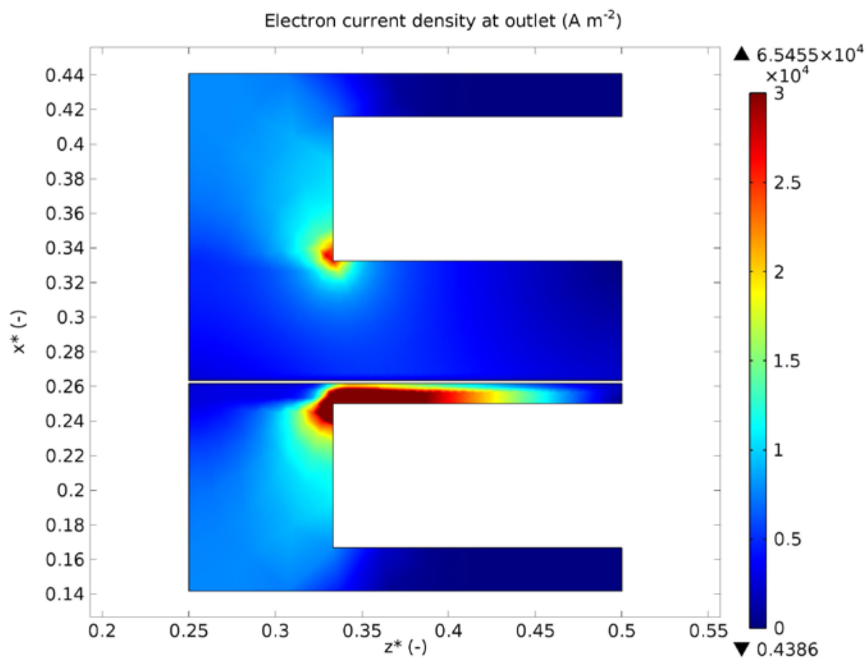

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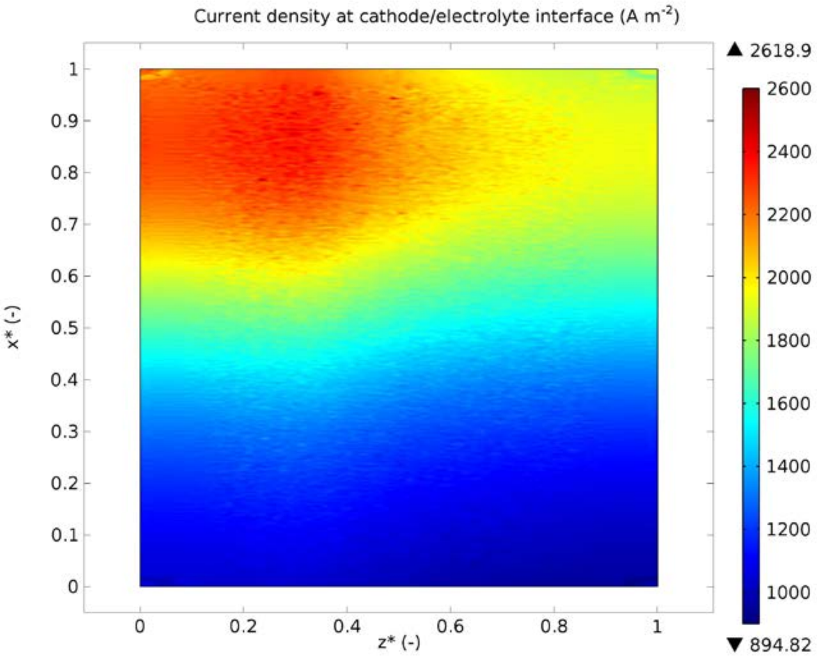
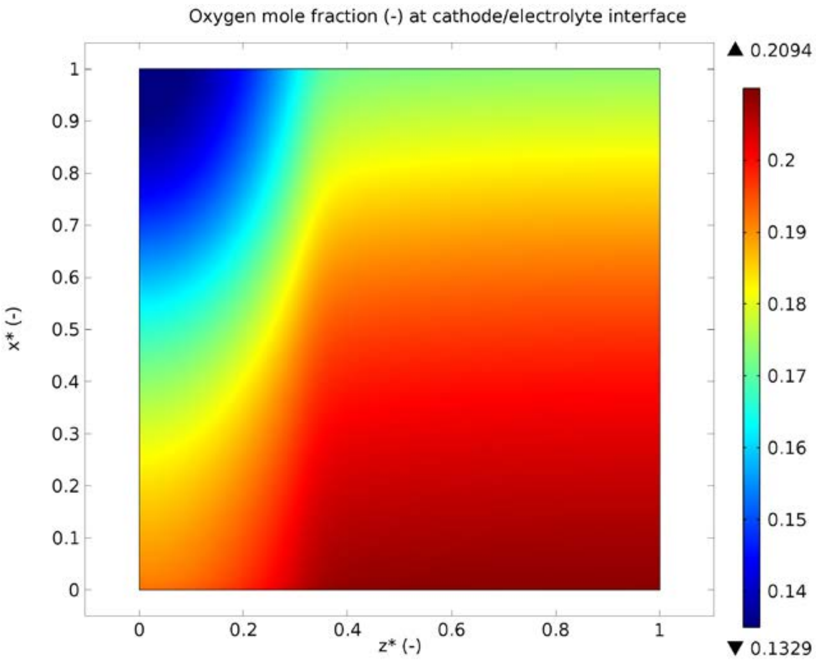
Results – Graded Electron Tortuosity





- The electron tortuosity is decreased under the fuel and air channels

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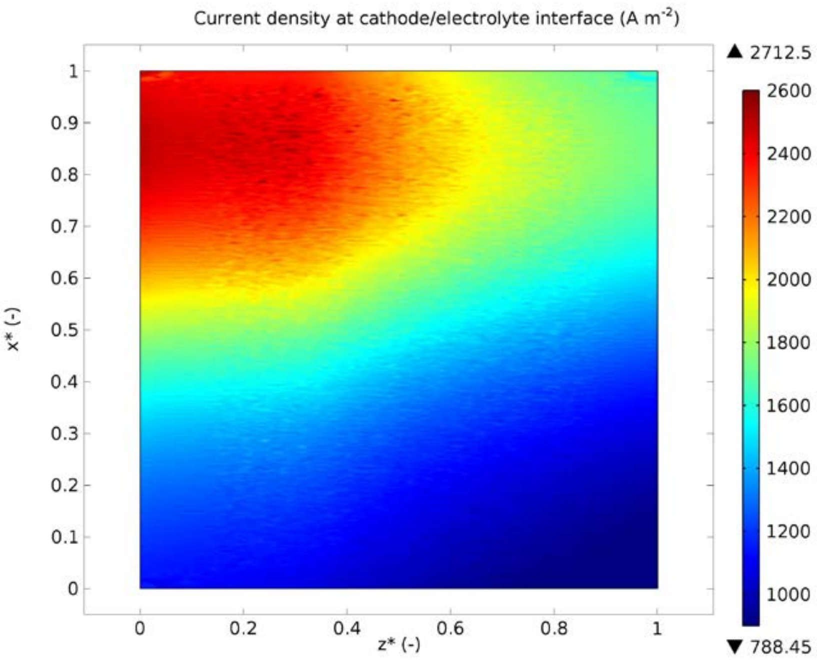
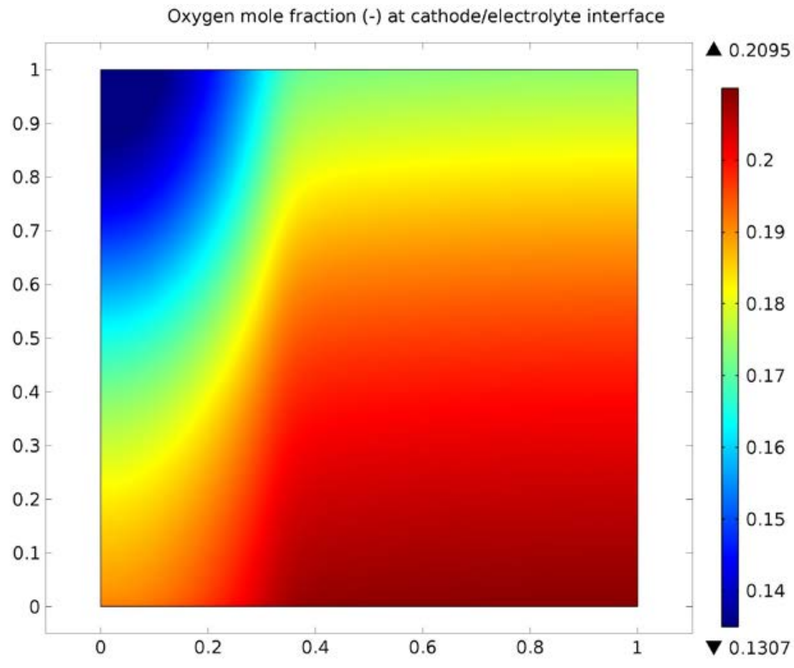
Results – Graded Electron/Ion Conducting Material Volume Fractions





The electron conducting material fraction is increased under the fuel and air channels

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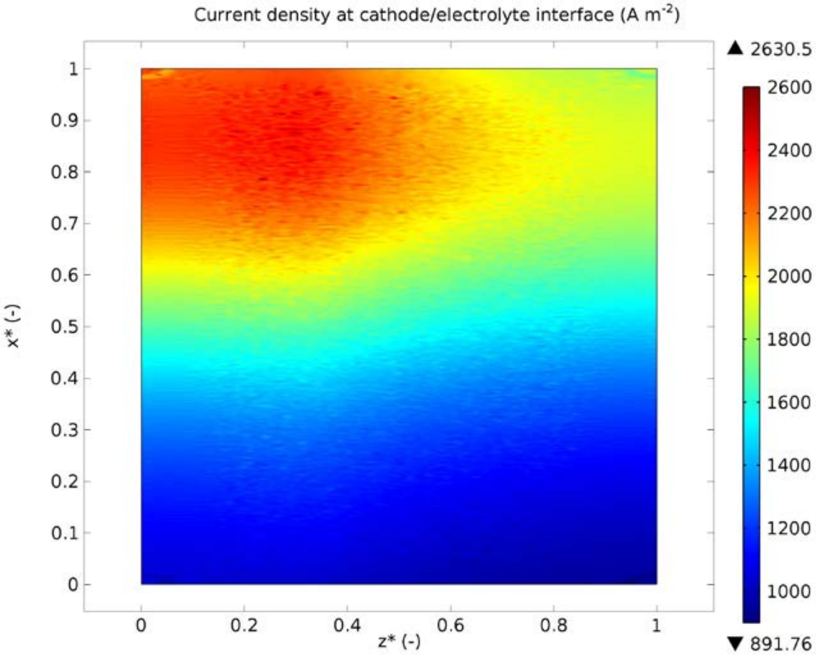
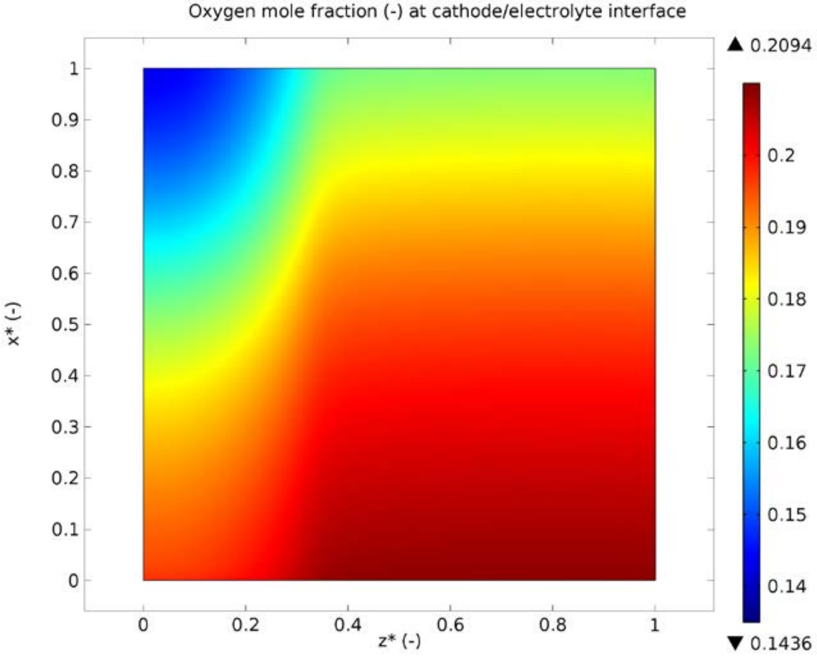
Results – Graded Pore Tortuosity





The pore tortuosity is decreased under the interconnect ribs

Conclusion

- Governing equations for heat, gas-phase species, electron, ion and momentum transport are implemented and coupled to kinetics describing electrochemical as well as internal reforming reactions.
- Grading the electron tortuosity (decreased under the fuel and air channels), the electron conducting material fraction (increased under the fuel and air channels) and the pore tortuosity (decreased under the interconnect ribs), in the direction normal to the electrode/electrolyte interface increases the performance (average ion current density) slightly.

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