Modeling & Simulation of tubular SOFC

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Fuel cells

Our interesting

AFC

SOFC

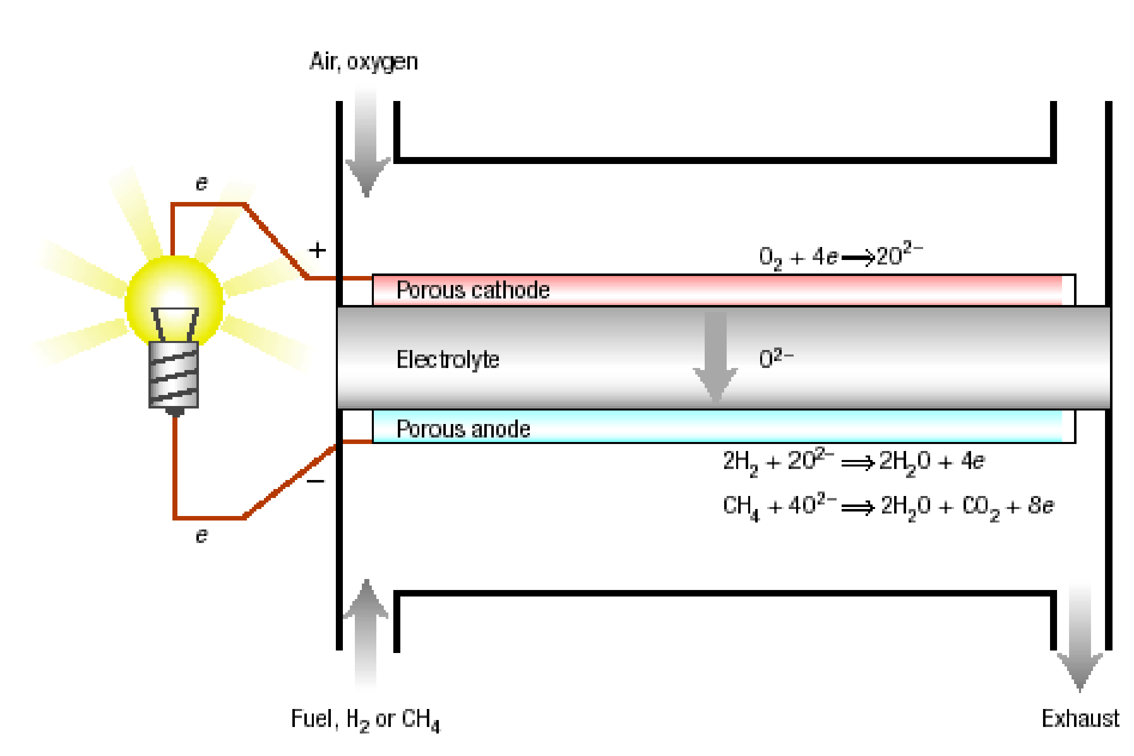
PAFC

PEMFC

MCFC

DMFC

Working Principle



Characteristics of tubular SOFC

High efficiency

Silent work

Clean generation of electric power

High fuel flexibility

What to model in tubular SOFC?

- *Micromodeling (1D, 2D): 1.interface 2.microstructure*
- *Cell (2D,3D): repeating unit*
- *Stack(3D): fuel reforming, heat exchange, after burning, etc.*
- *System(0D): CHP, BOP, etc.*

Objective in tubular SOFC modeling

1. Performance modeling

Explain phenomena of the observations

Predict behaviour

2. Design of the cell structure

long life

low losses

high output

low thermal stress ……

Our work

1.Effects of different current collecting modes to the performance of anode supported tubular SOFC

2. Thermal phenomena in the anode supported tubular SOFC

Model assumptions

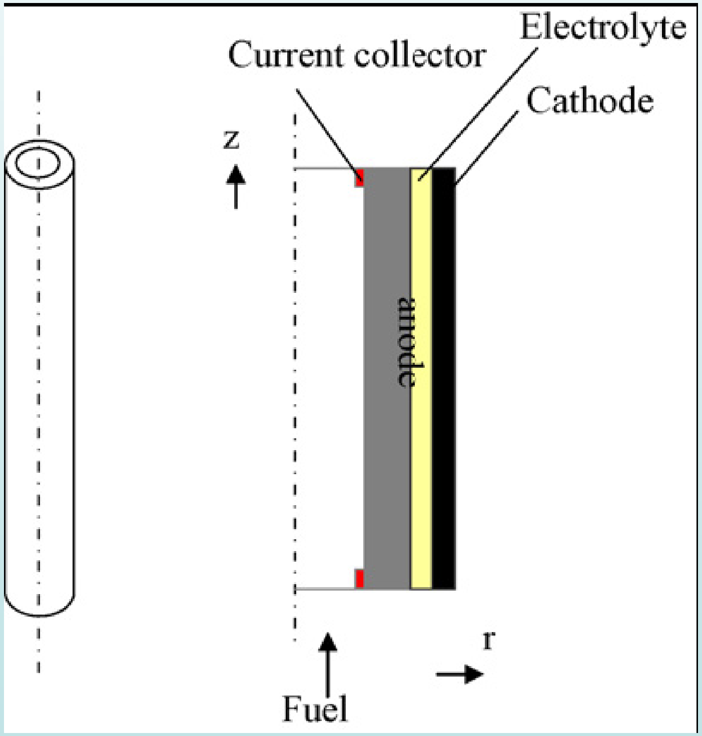
Model is based on steady state.

Gas flows in the channels are laminar.

Reactant gas mixtures are approximated as ideal gas and incompressible.

Fuel cell operates with 100% current efficiency.

Model is assumed to be isothermal, and the cell run at 800 °C.



Schematic diagram of a micro-tubular geometry in 2D.

Electrochemical Equation

$$\frac{1}{2}O^2 + 2e^- \rightarrow O^{2-}$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

$$H_2 + 2O^{2-} \rightarrow H_2O + 2e^-$$

$$i = i_0\left\{\exp\left(\beta\frac{n_e F\eta_{Act}}{RT}\right) - \exp\left[-(1-\beta)\frac{n_e F\eta_{Act}}{RT}\right]\right\}$$

$$\eta_{act} = v_{rev} - \mathrm{abs}(v_{electrode} - v_{electrolyte})$$

Governing equations

- ***Electronic charge***

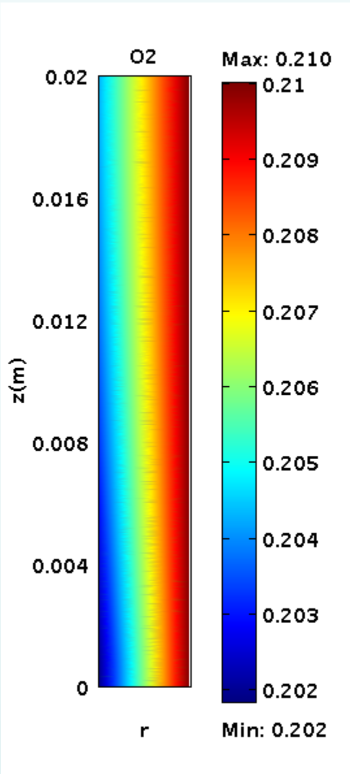
$$-\nabla(\sigma \cdot \nabla \phi) = 0$$

- ***Momentum transport equations***

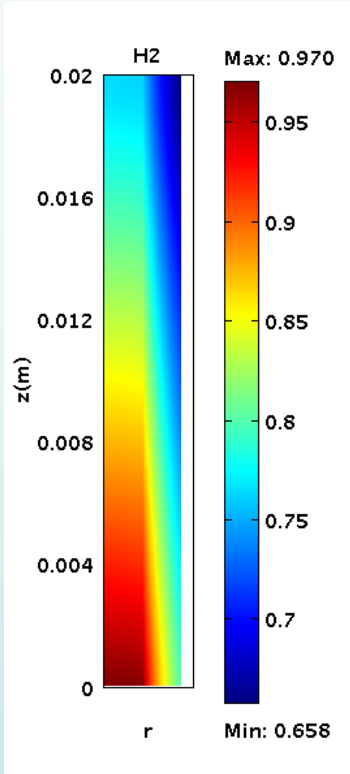
$$\rho(u \cdot \nabla u) - \mu(\nabla^2 u) + \nabla P = 0$$

- ***mass transport equations***

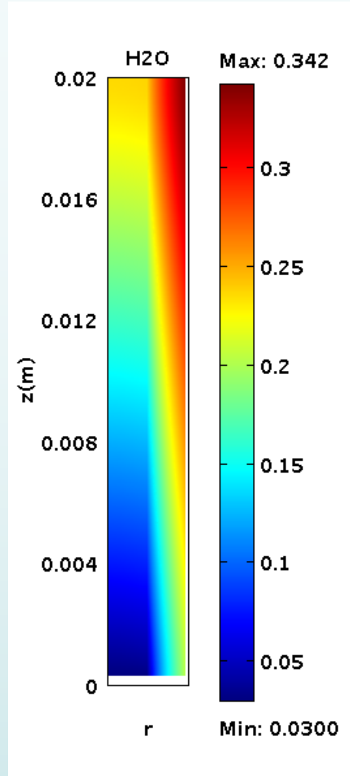
$$\nabla(-D_{ij} \cdot \nabla c_i + c_i \cdot u) = 0$$



a

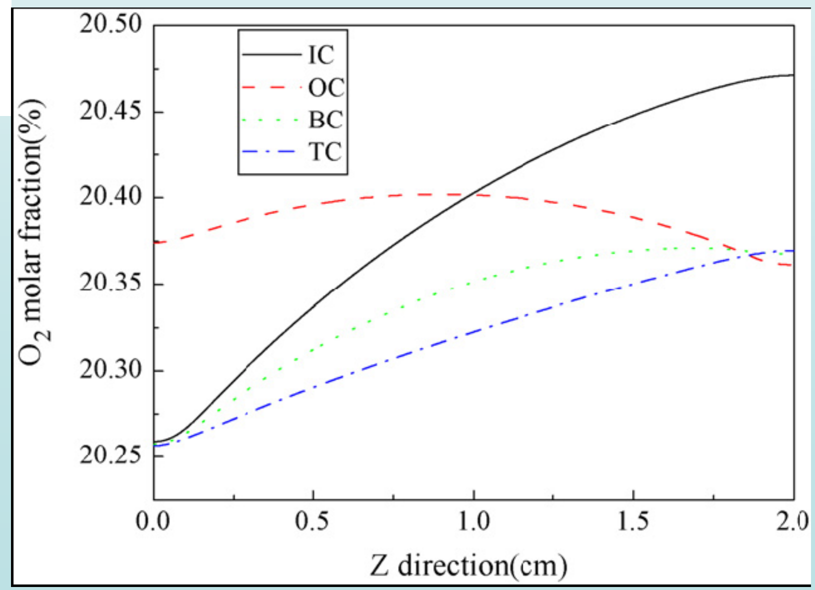


b

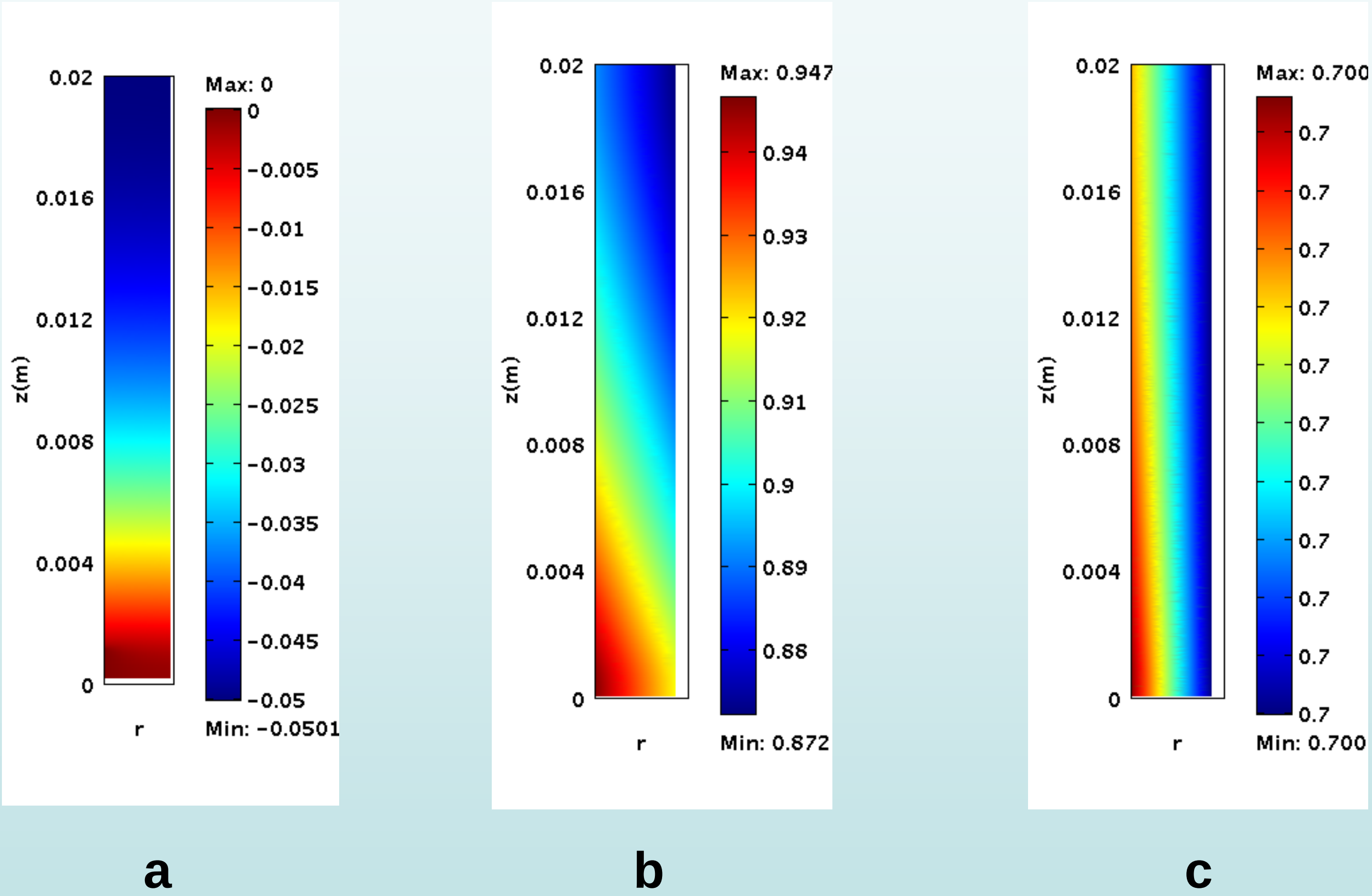


c

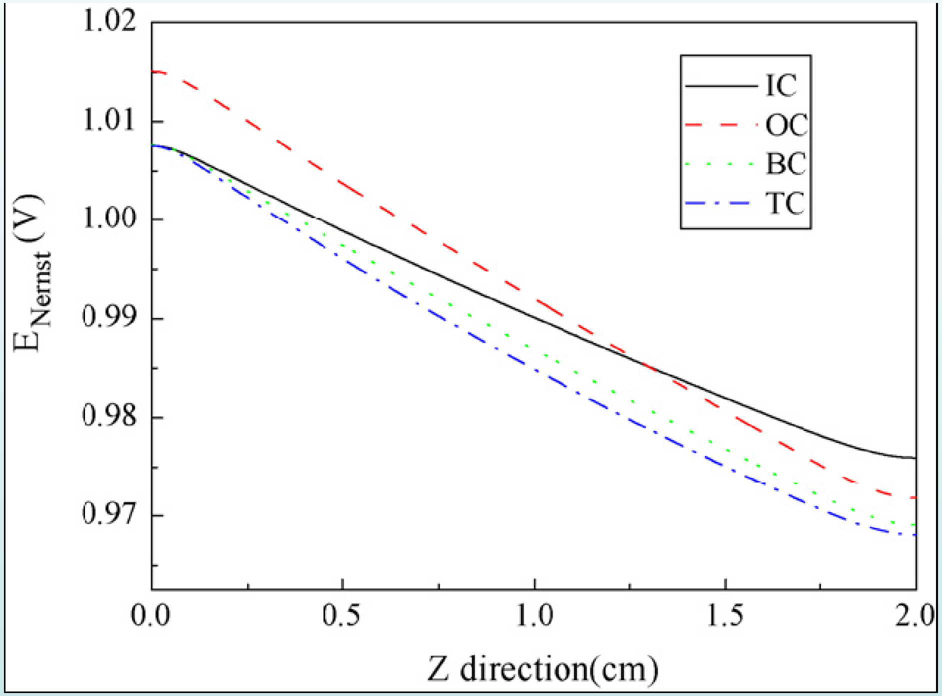
d

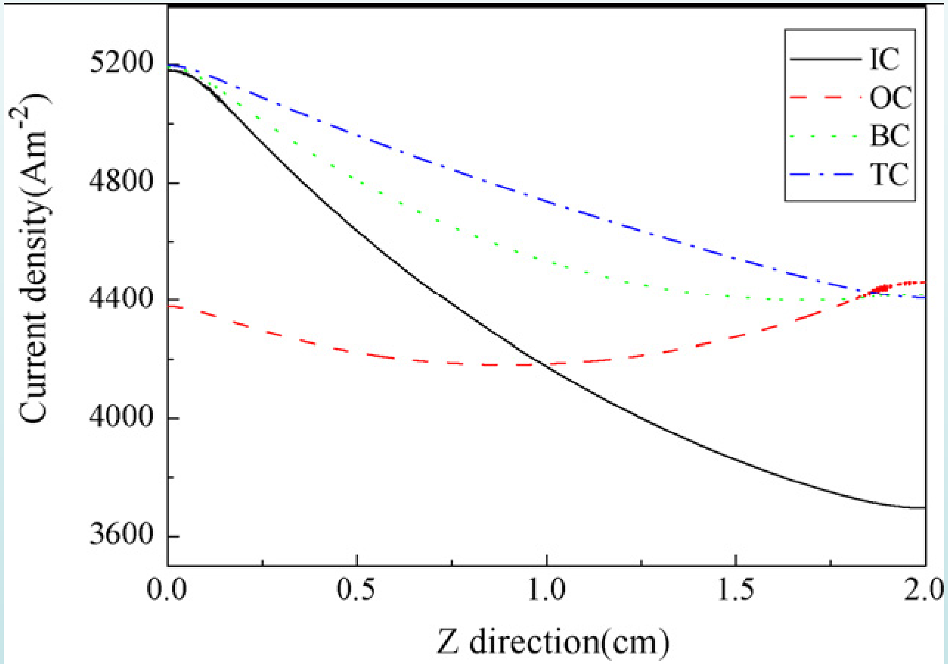


Molar fraction distribution of O2, H2, H2O



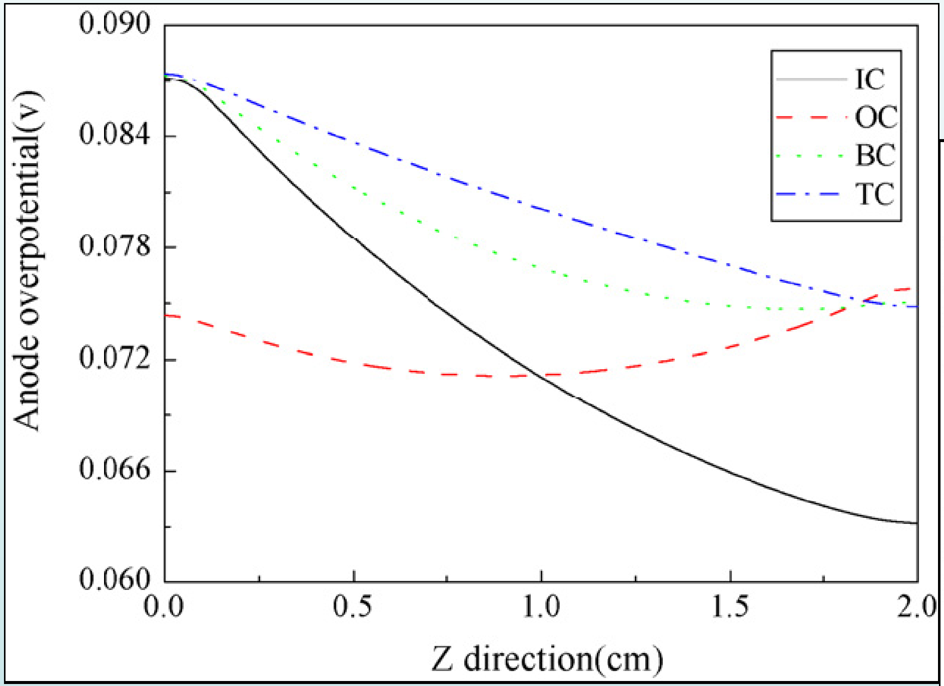
Distributions of anode (a) and cathode (b) electric potentials, electrolyte (c) potential.



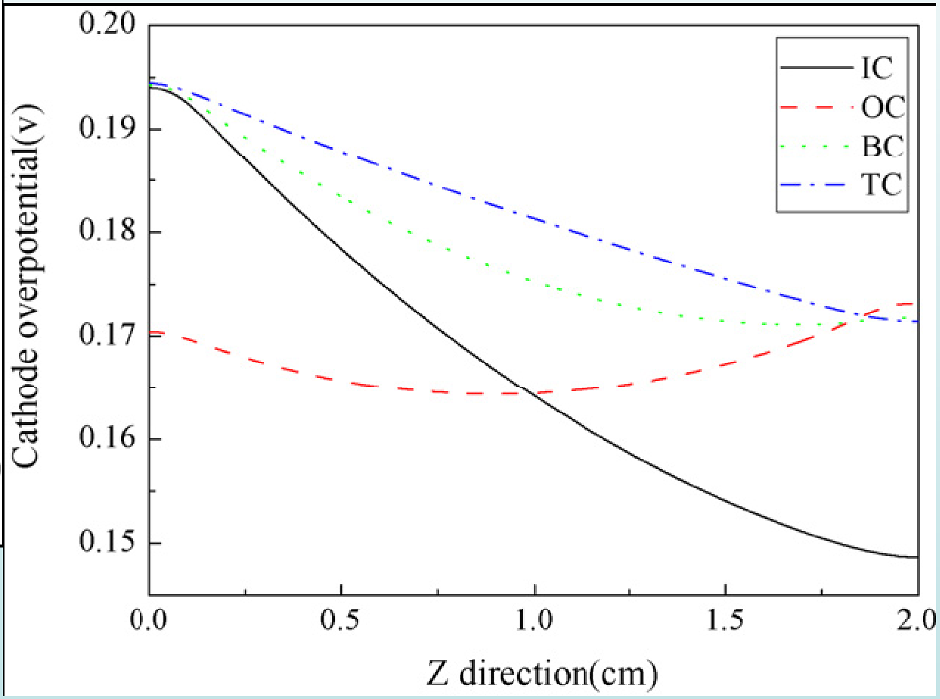


Distribution of E_{Nernst} along the anode/electrolyte interface

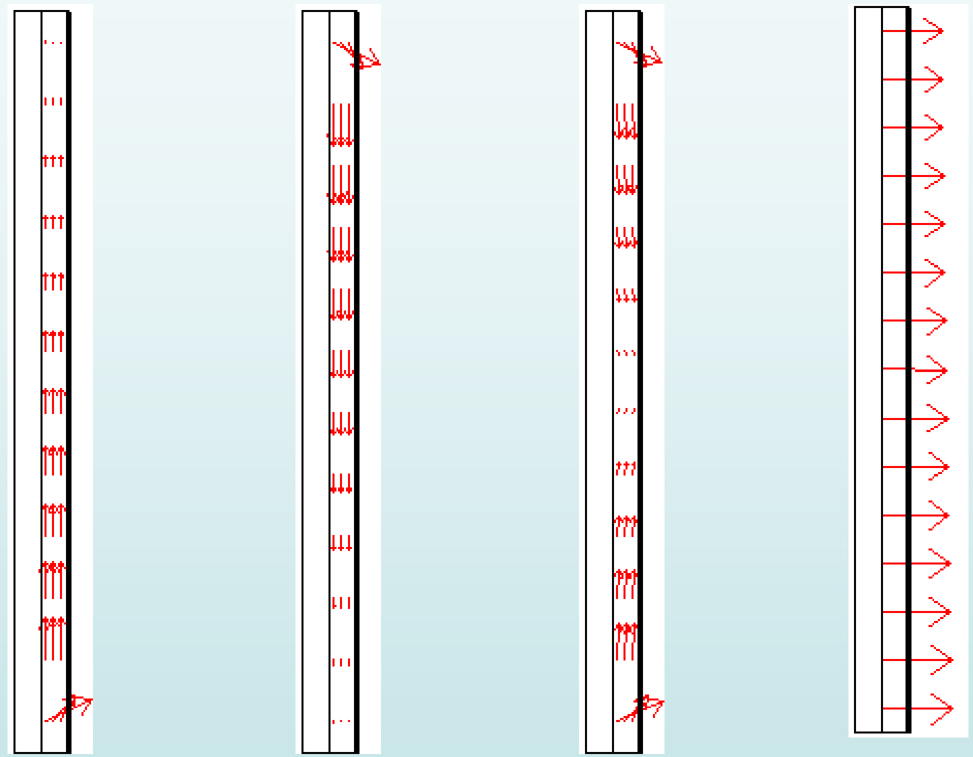
Distribution of current density along the anode/electrolyte interface



Distribution of anode overpotential along the anode/electrolyte interface

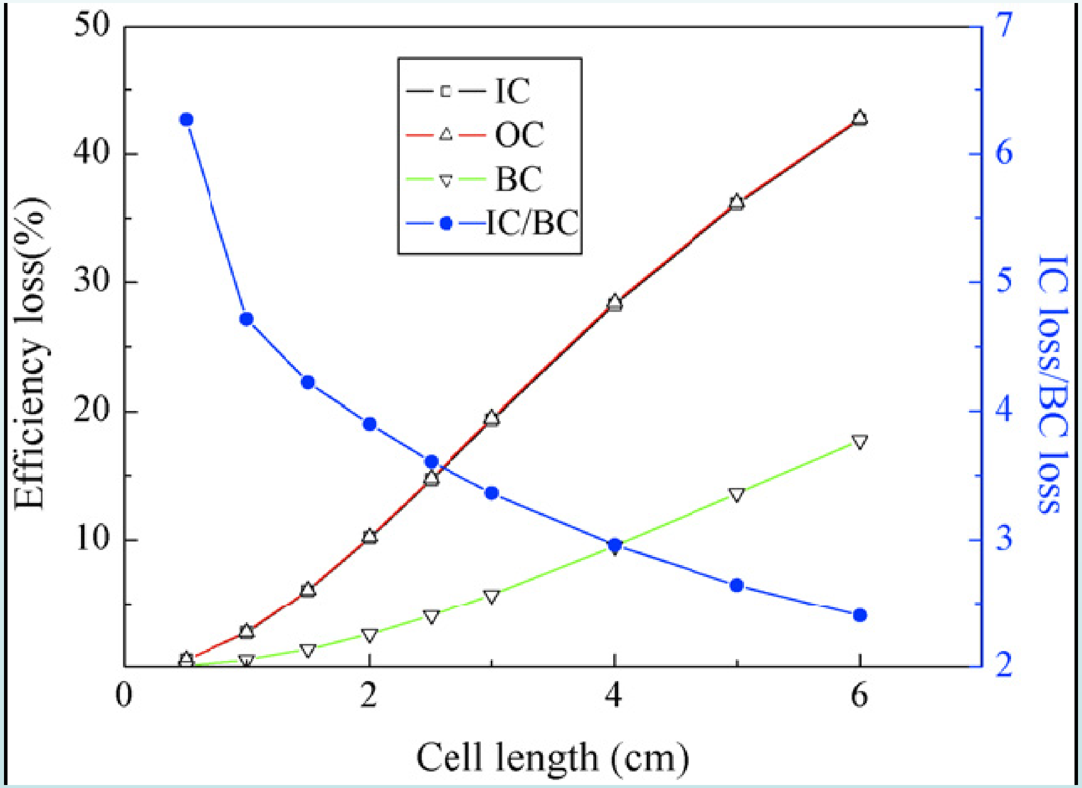


Distribution of cathode overpotential along the anode/electrolyte interface



a b c d

Vector plots of current density inside anode under IC (a), OC (b), BC (c) and TC (d) modes.



$$\text{loss} = 1 - \frac{I_i}{I_{TC}}$$

The cell efficiency loss and IC loss/BC loss as a function of anode tube length.

2. Thermal phenomena in the anode supported tubular SOFC

Heat generation

$$q_{rev,a} = T \cdot \Delta S_a \frac{i_a}{2F}$$

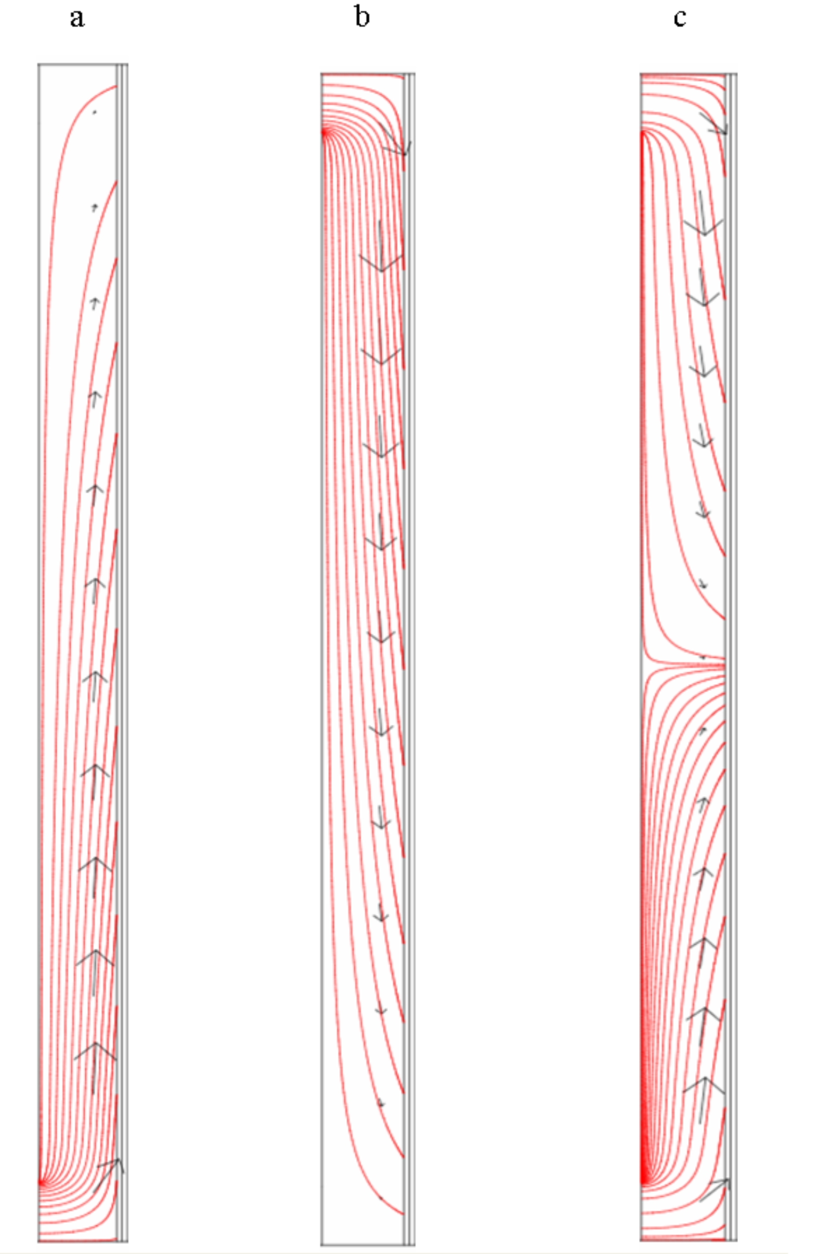
$$q_{irr,a} = \eta_{act,a} \cdot i_a$$

$$Q = \sigma \cdot \nabla^2 \phi$$

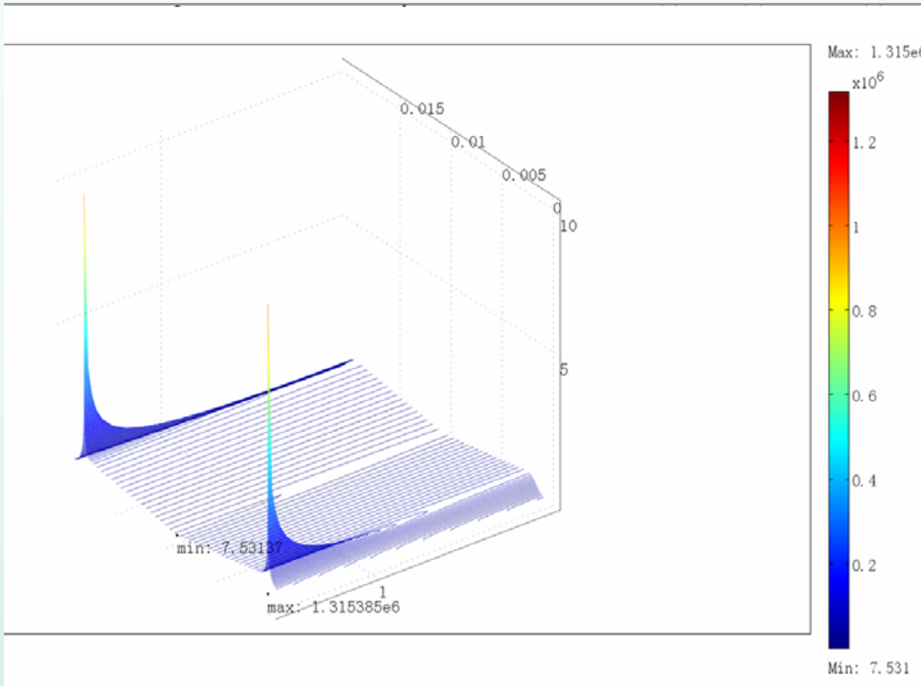
Heat transfer

Conductive and convective equation

$$\nabla(-k \cdot \nabla T) + \rho \cdot C_P \cdot u \cdot \nabla T = Q$$

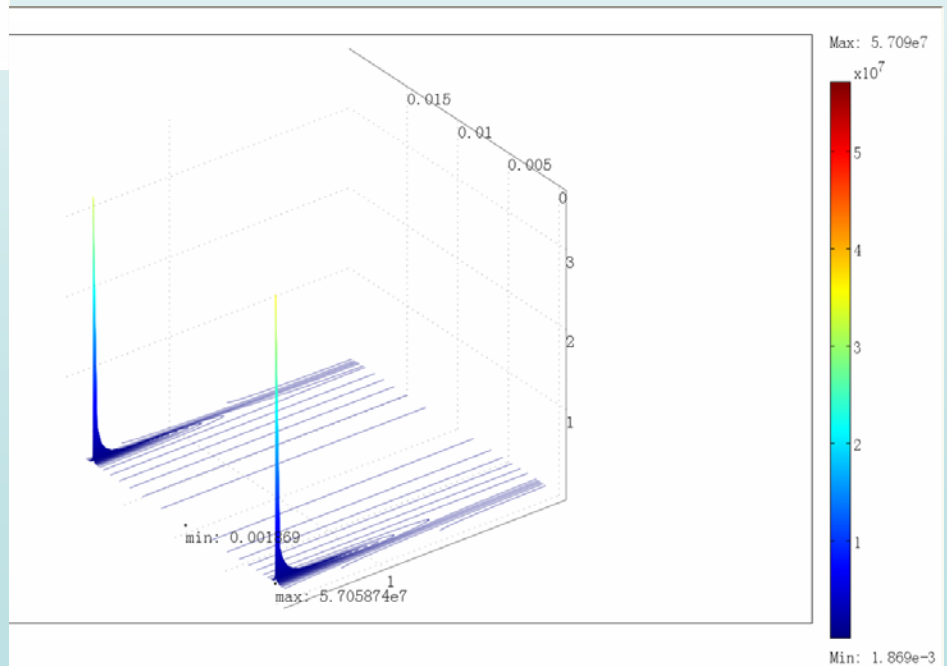


Vector plots of current density inside anode under IC (a), OC (b) and BC (c) modes.



3D contour plot of the anodic current density (A/m2)

3D contour plot of the anodic resistive heating (W/m3)



Conclusion

- **Simulation well reflects the current flow in an real cell.**

- **Efficiency loss under the BC mode was about 2–6-fold lower than others.**

- ***current collector area has less effect on current collecting.***

- ***A very high resistive heating point is found at anode, but it is not a hot spot because of the rapid heat transfer rate.***

Acknowledgments

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Thank you!