Numerical modelling of a serpentine channel SOFC for elevated pressure applications

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Introduction

Solid Oxide Fuel Cell (SOFC) is an electrochemical device that directly converts the chemical energy into the electrical energy through electrochemical reaction.
SOFC is one of the promising alternative to conventional power plants due to its higher efficiency, fuel flexibility, and possibilities of Combined heat and power generation due to its high operating temperature.

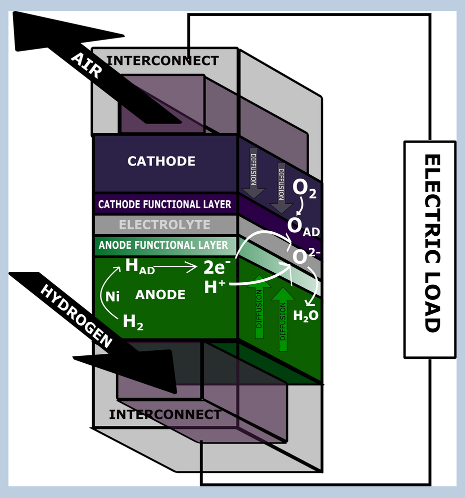

Figure 1: Schematic Diagram of an SOFC

Materials and Geometry

Components Electrolyte: 8-YSZ, Cathode: Ni/YSZ, Anode: LSM

Working Fluids Fuel: Hydrogen, Oxidant: Air.

Geometry Type Segmented Serpentine channel SOFC

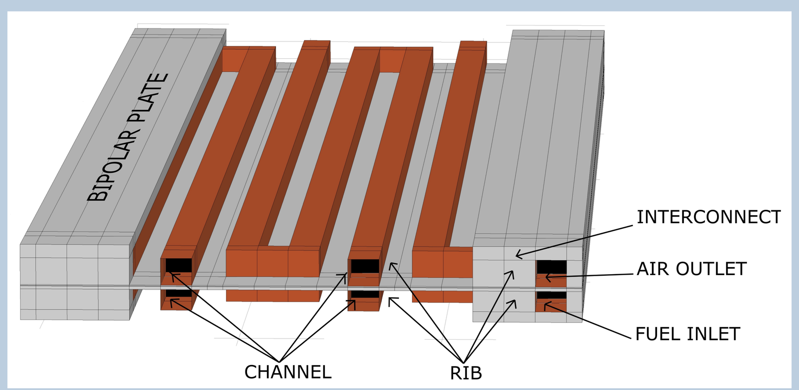

Figure 2: Serpentine plate geometry

Conclusion

Pressurisation of SOFC is an essential part of the SOFC and gas turbine combined cycles. A single serpentine channel SOFC performance is investigated in the (absolute) pressure range of 1 bar (atmosphere) to 4 bar.It is found that both the flow characteristics as well as electrochemical characteristics are widely affected by the system pressurisation. Pressurisation has the potential to raise the power output of the SOFC model and can reduce the non-uniformity in the current generation along the plate. Further, the study also reveals that the pressurization is also increased as the cell temperature is raised.

References

References

[1] Deepra Bhattacharya, Jayanta Mukhopadhyay, Nayan Biswas, Rajendra Nath Basu, and Prasanta Kumar Das. Performance evaluation of different bipolar plate designs of 3d planar anode-supported {SOFCs}. *International Journal of Heat and Mass Transfer*, 123:382 – 396, 2018.

Acknowledgements

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Modelling Methodology and Validation

Physics of mass, momentum, heat transfer have coupled with cell electrochemistry using following governing equations:

Free fluid flow in channels : Navier Stokes Equation

Subsurface Flow in Electrodes : Brinkman Equation

Heat Transfer : Generalised Energy Equation

Electrochemistry : Nernst Equation, Butler-Volmer equation

The model is uniformly meshed using $\sim 10^6$ cuboidal elements customized to be finer near the reacting interfaces. A direct solver, PARDISO of COMSOL Multiphysics is employed by setting a relative tolerance of 10^{-5} to solve the equations with suitable boundary conditions[1].

Results

Velocity profile in pressurised SOFC:

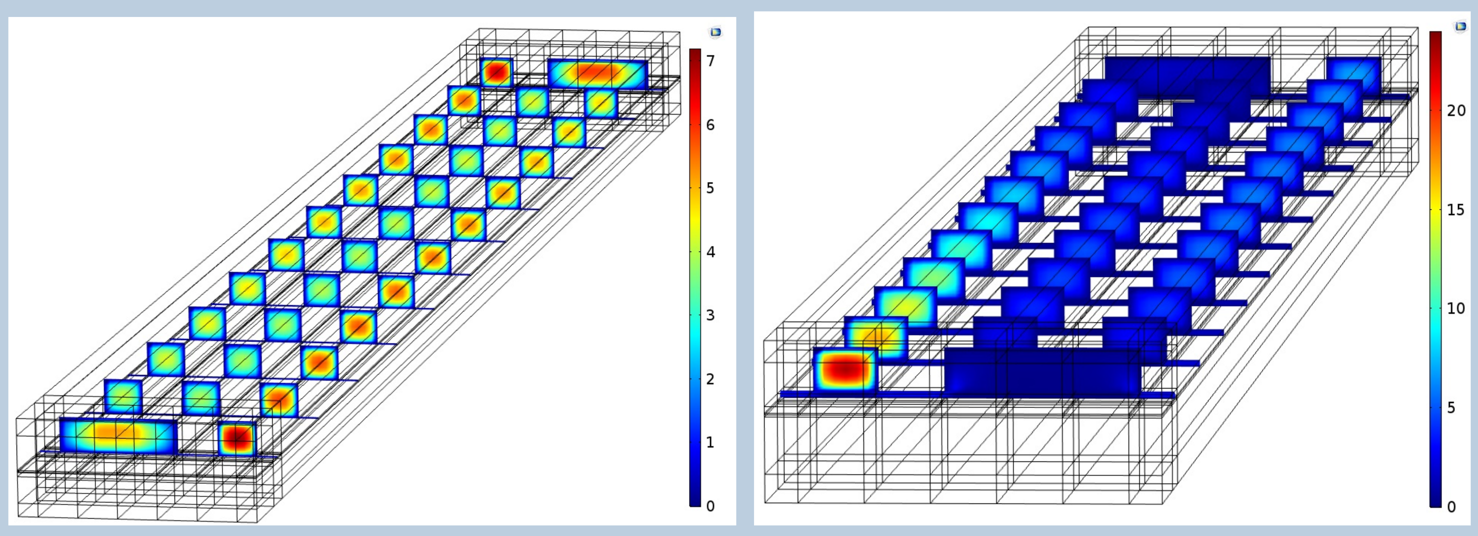

Figure 3: velocity profile at pressurised condition: Cathode (left); Anode (right)

Figure 3 depits the velocity distribution in cathode and anode channel of the serpentine SOFC at elevated pressure.

Spatial Distribution of Hydrogen along the flow channel: Figure ?? depicts the hydrogen distribution along the serpentine flow channel at ambient pressure condition as well as at pressurised condition. It shows that at elevated pressure, hydrogen concentration is more uniformly distributed; that also helps to predict the uniform current generation at elevated pressure. Non uniformity of current density in plate is one of the major cause of cell depletion; which can be avoided by pressurizing the system.

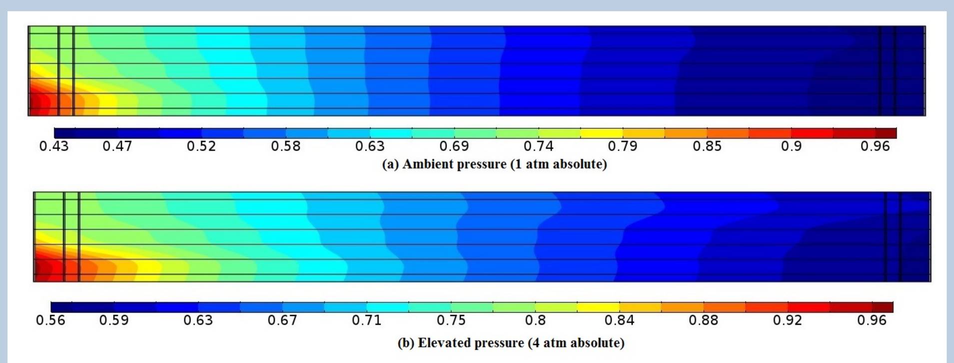

Figure 4: H_2 concentration along the flow channel

Distribution of Temperature in the SOFC:

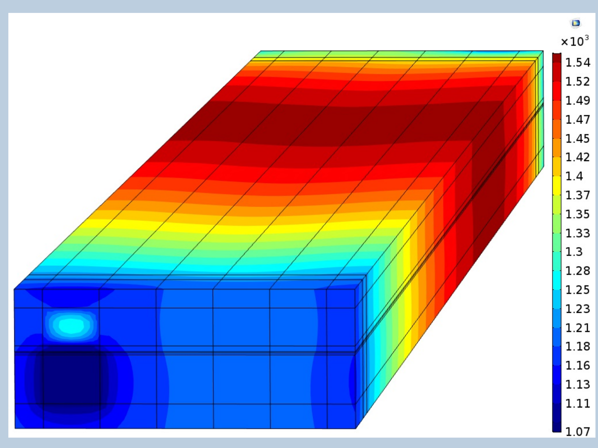

Figure 5: Temperature profile of SOFC model at elevated pressure

VI characteristics:

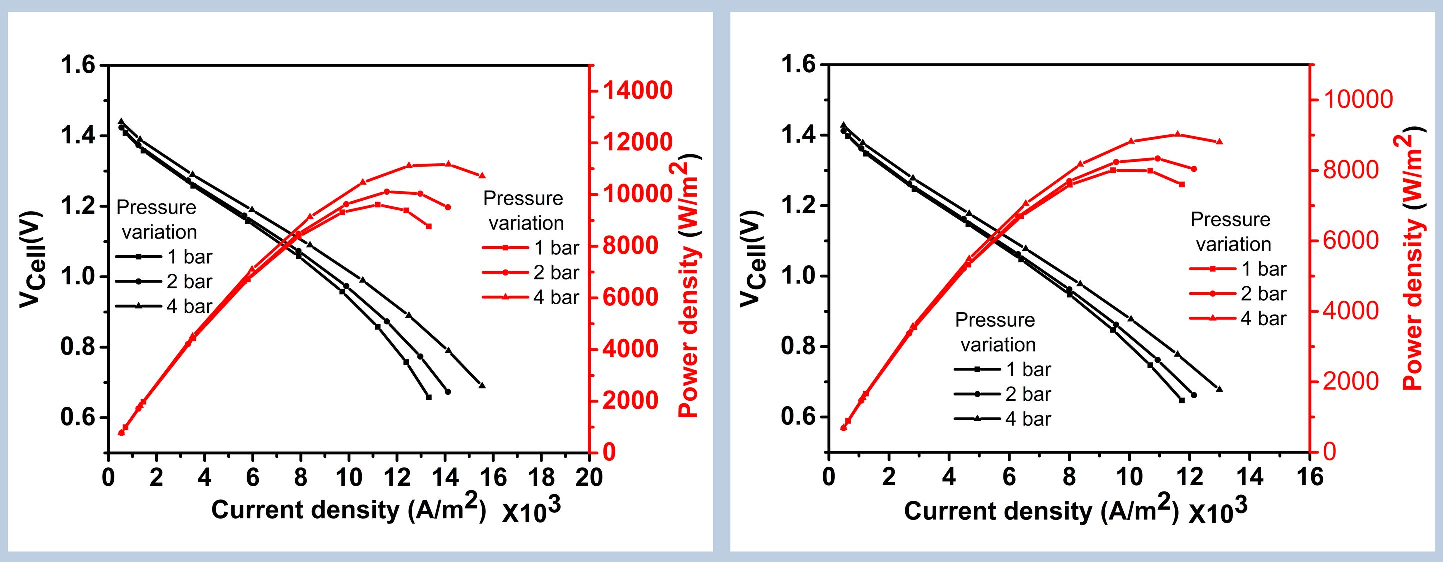

Figure 6: Variation of VI characteristics with pressuree: 1073 K (left); 1023 K (right)