

# In-House Developed Multiphysics Simulation for the Performance of Solid Oxide Cells (SOCs)

Research &  
Innovation Center



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## Introduction

### Background and Motivation

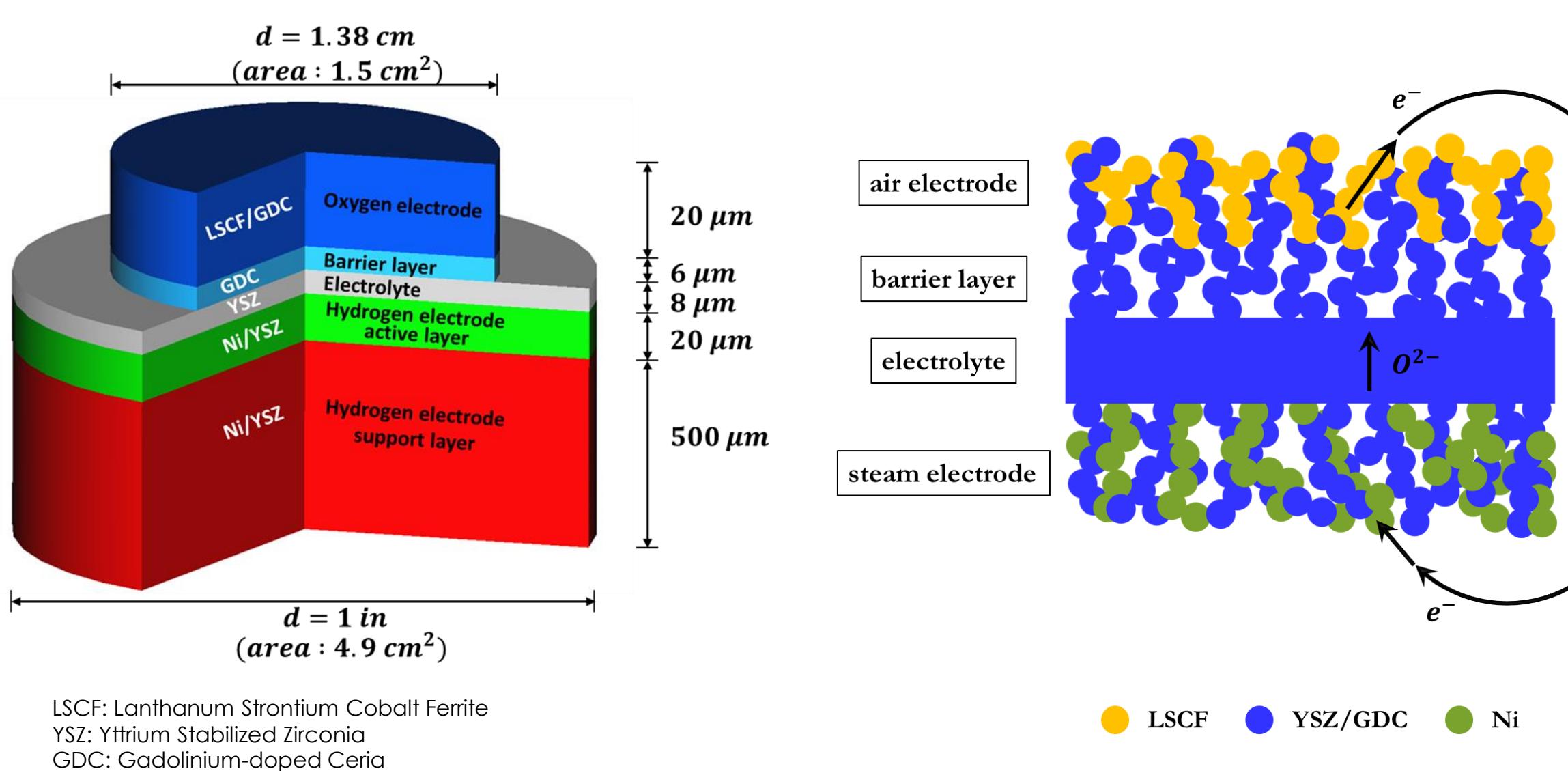
- Reversible solid oxide cells(r-SOCs) are an enabling energy storage/production technology for a dynamic grid environment. Reversible operation requires strong working knowledge of fuel cell (SOFC) and electrolyzer (SOEC) operation.
- Performance degradation of SOECs has been observed; however, the details of physical processes related to the performance degradation remain unknown.

### Purpose of the Study

- Multiphysics simulations were performed to investigate the performance degradation of solid oxide electrolysis cells under various working conditions.

## Multiphysics Modeling

### Cell configuration & working conditions



### Governing equations

- Charge conservation (electron-conducting phase)

$$a_{int} C_{DL} \frac{\partial}{\partial t} (\varphi_e - \varphi_i) + \nabla \cdot (-\sigma_e \nabla \varphi_e) = i_F$$

double layer capacitor    charge transport    electrochemical reactions

- Species transport

$$\varepsilon \frac{\partial \phi}{\partial t} = \nabla \cdot (D_\phi^{eff} \nabla \phi) - S_\phi$$

diffusion    consumption/production rate

- Electrochemical model (Butler-Volmer model in this study)

Steam electrode:

$$i_{F,S} = i_{0,S} (P_{H_2}^\infty)^a (P_{H_2O}^\infty)^b \left\{ \frac{P_{H_2}}{P_{H_2}^\infty} \exp \left[ \frac{(1-\alpha)nF\eta_S}{RT} \right] - \frac{P_{H_2O}}{P_{H_2O}^\infty} \exp \left[ -\frac{\alpha nF\eta_S}{RT} \right] \right\}$$

Air electrode:

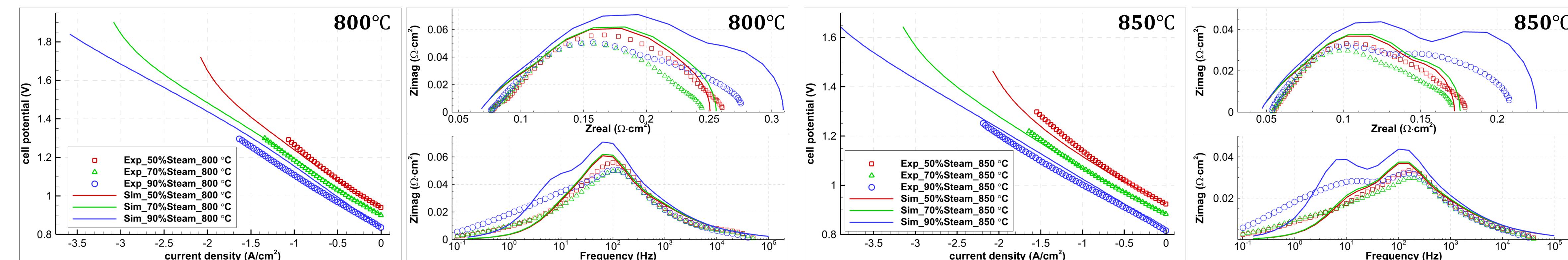
$$i_{F,A} = i_{0,A} (P_{O_2}^\infty)^m \left\{ \frac{P_{O_2}}{P_{O_2}^\infty} \exp \left[ -\frac{\alpha nF\eta_A}{RT} \right] - \exp \left[ \frac{(1-\alpha)nF\eta_A}{RT} \right] \right\}$$

### References

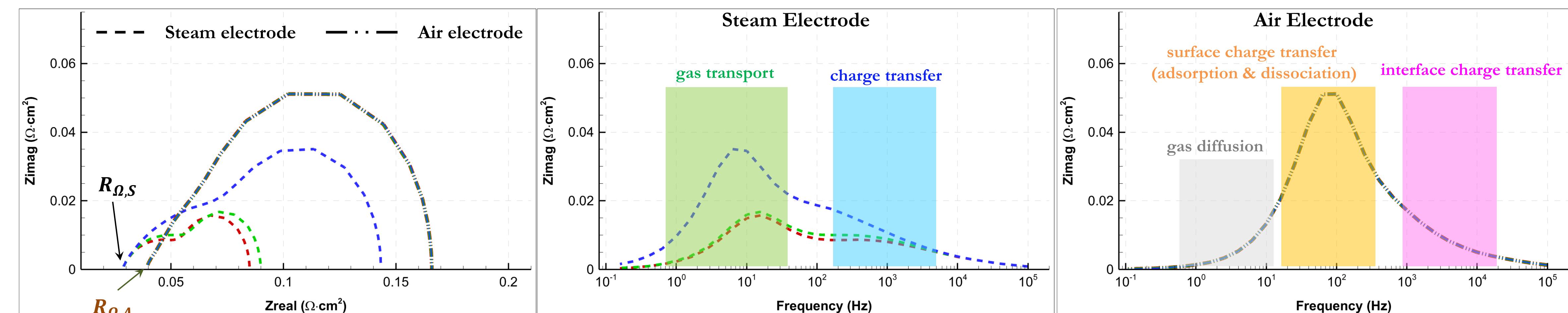
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## Results

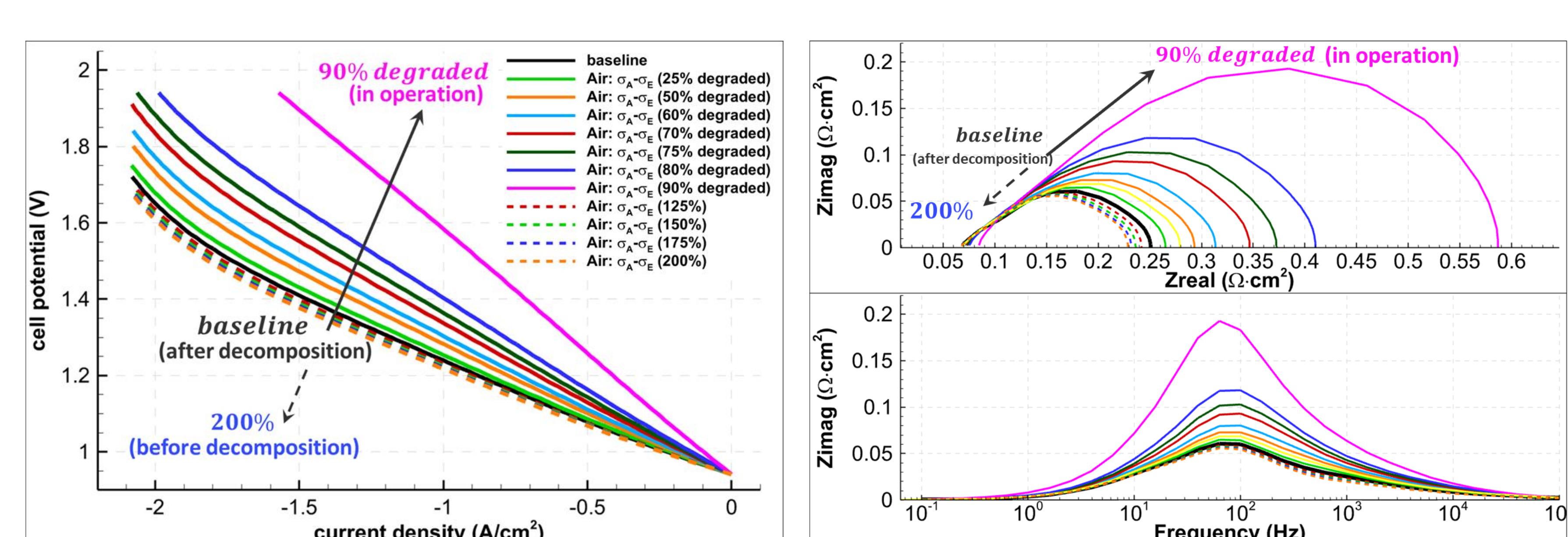
### Calibration of the multiphysics simulation



### Resistance of electrodes (800°C)



### Effects of electrical conductivity on the cell performance



## Summary & Future Work

- Multiphysics simulations were performed to study the degradation of solid oxide electrolysis cells under various working conditions.
- Resistance components of steam electrode and air electrode were extracted from simulated impedance behavior.
- The effects of electrical conductivity of air electrode (decomposition) on the performance was investigated, which can also be related to performance degradation during operation.

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