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Introduction

Background and Motivation

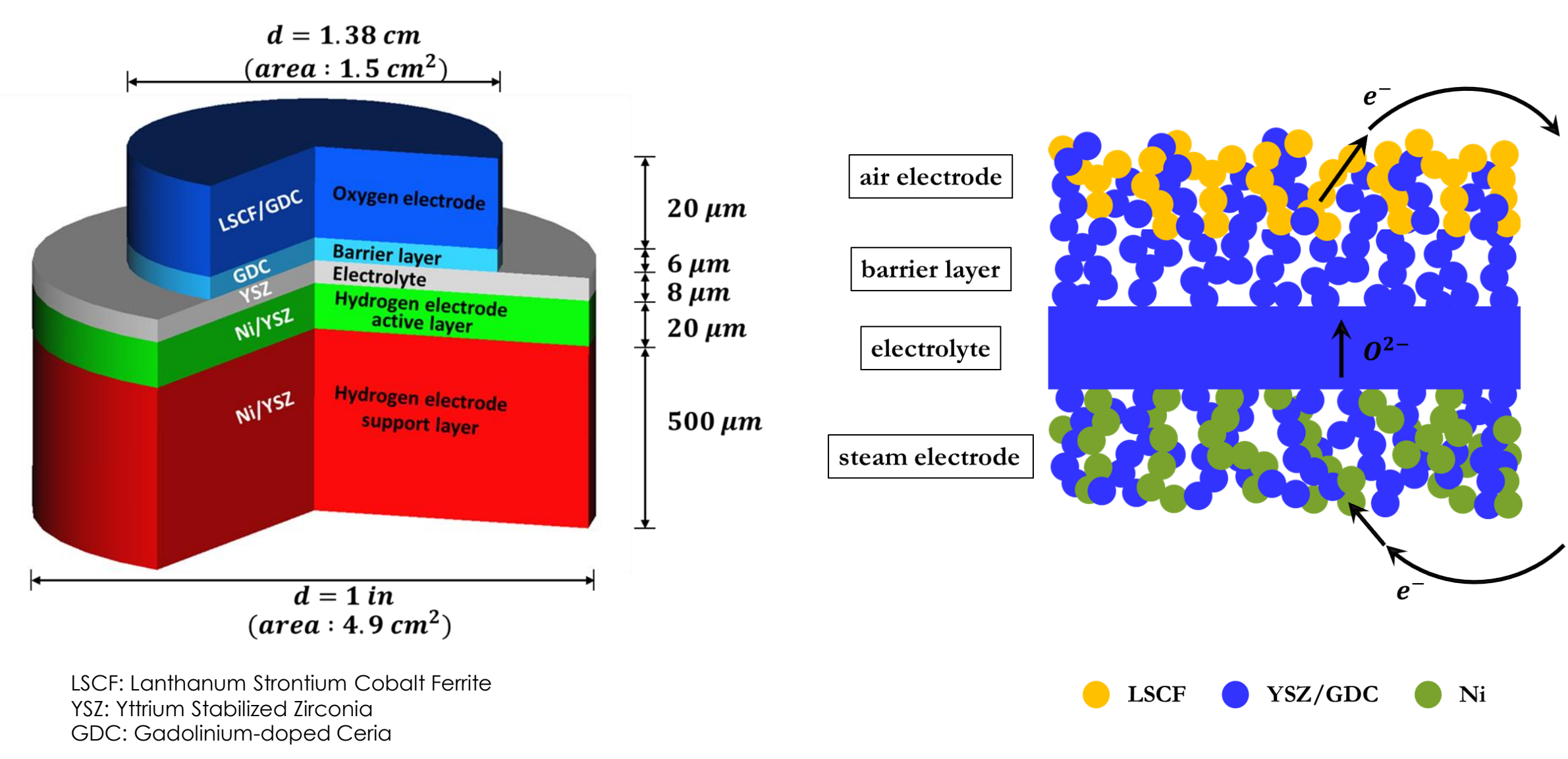
- Reversible solid oxide cells(r-SOCs) are an enabling energy storage/production technology for a dynamic grid environment. Reversible operation requires strong working knowledge of fuel cell (SOFC) and electrolyzer (SOEC) operation.
- Performance degradation of SOECs has been observed; however, the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

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

double layer capacitor charge transport electrochemical reactions

- Species transport

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

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:

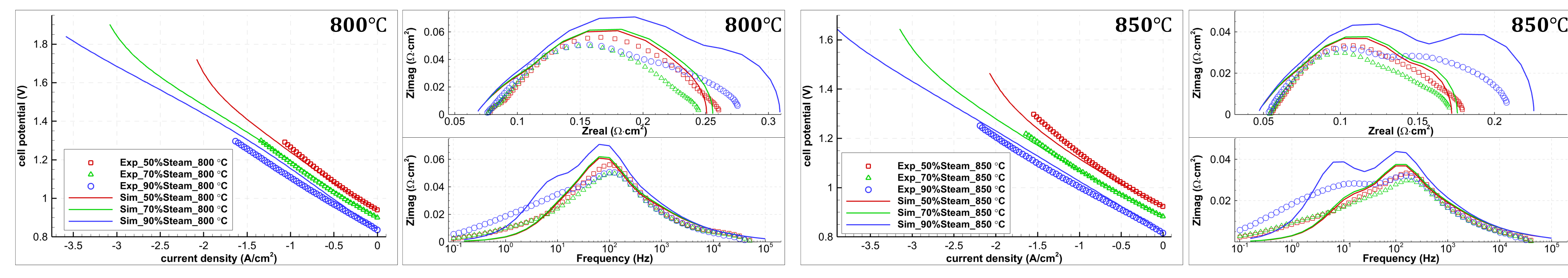
$$i_{F,A} = i_{0,A} (P_{O_2}^{\infty})^m \left[\frac{P_{O_2}}{P_{O_2}^{\infty}} \exp\left[-\frac{\alpha nF\eta_A}{RT}\right] - \exp\left[\frac{(1-\alpha)nF\eta_A}{RT}\right] \right]$$

References

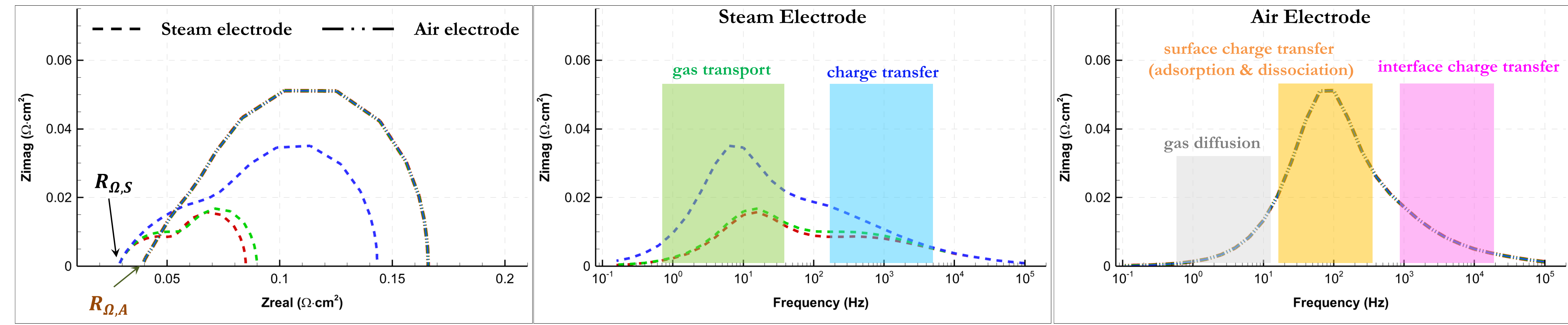
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Results

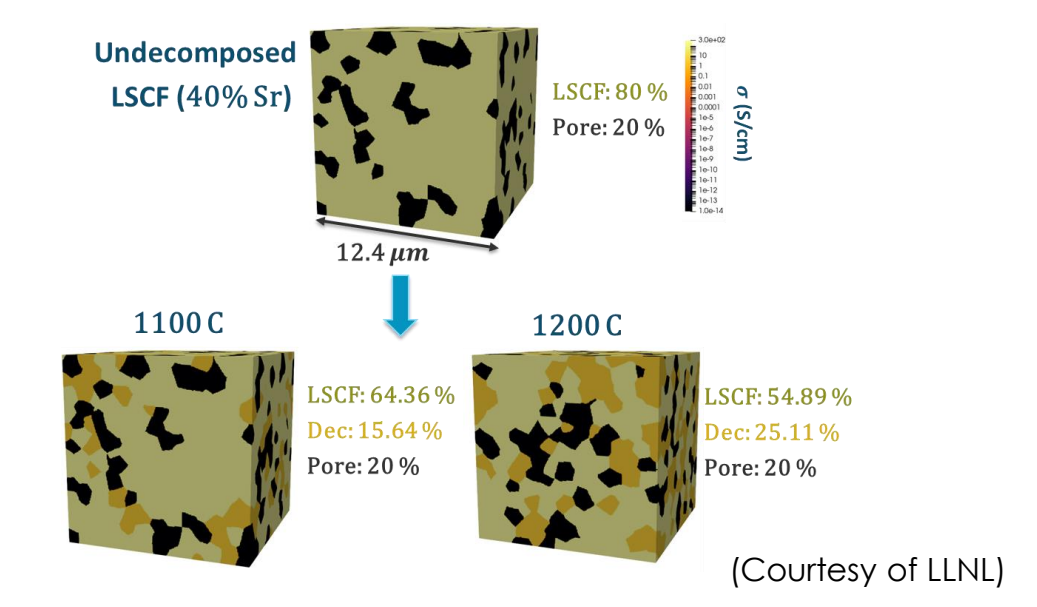
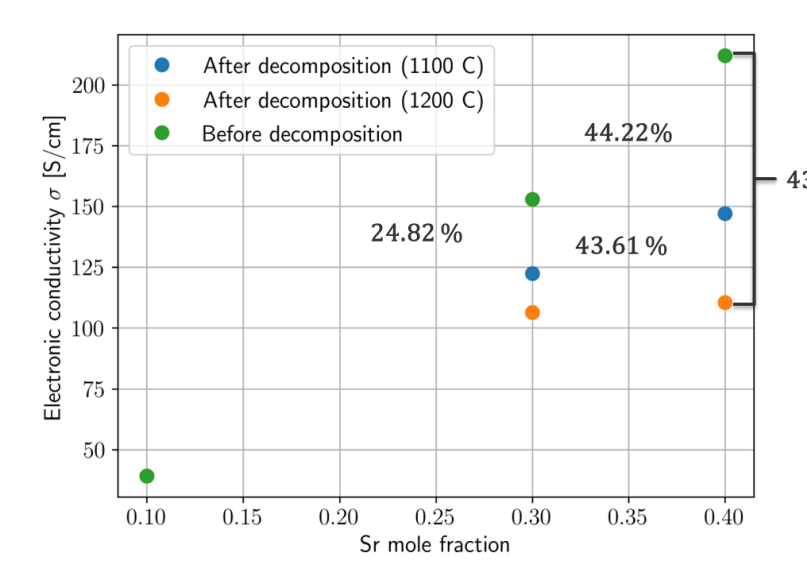
Calibration of the multiphysics simulation



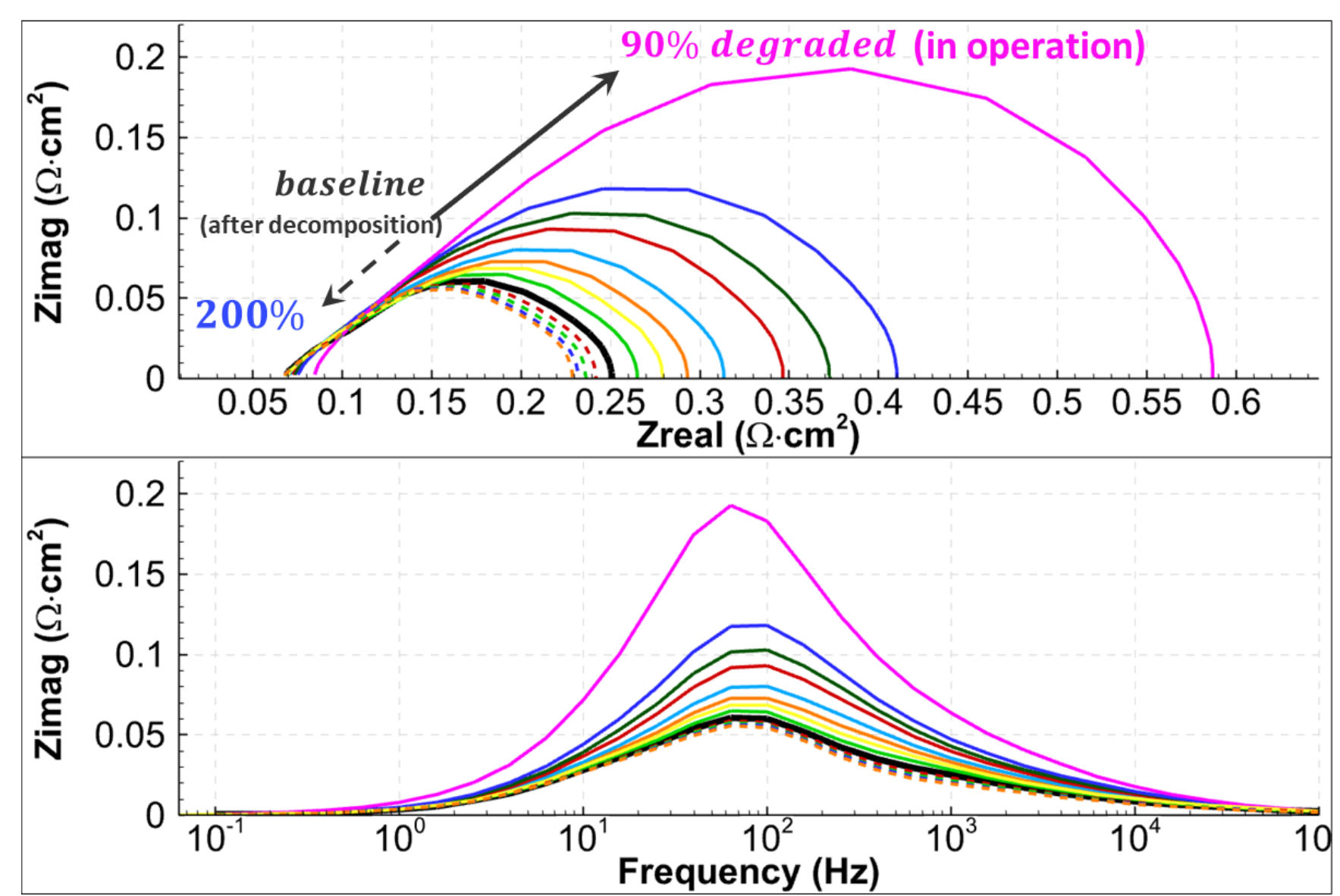
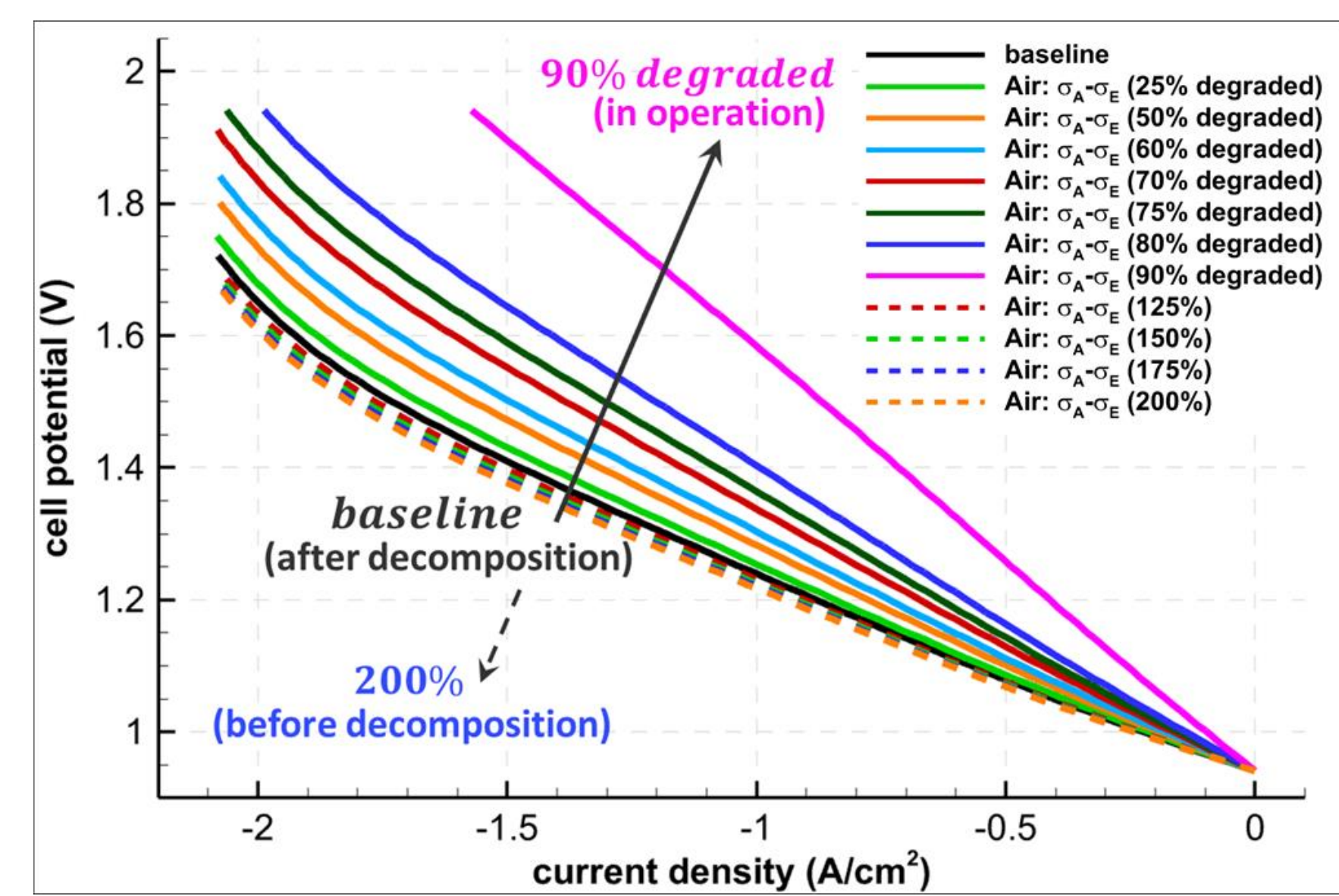
Resistance of electrodes (800°C)



Effects of electrical conductivity on the cell performance



Effective electronic conductivity of the porous LSCF electrode is lowered by the formation of the spinel phase



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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