Exploring the microstructure-performance behaviors of reversible solid oxide fuel cells

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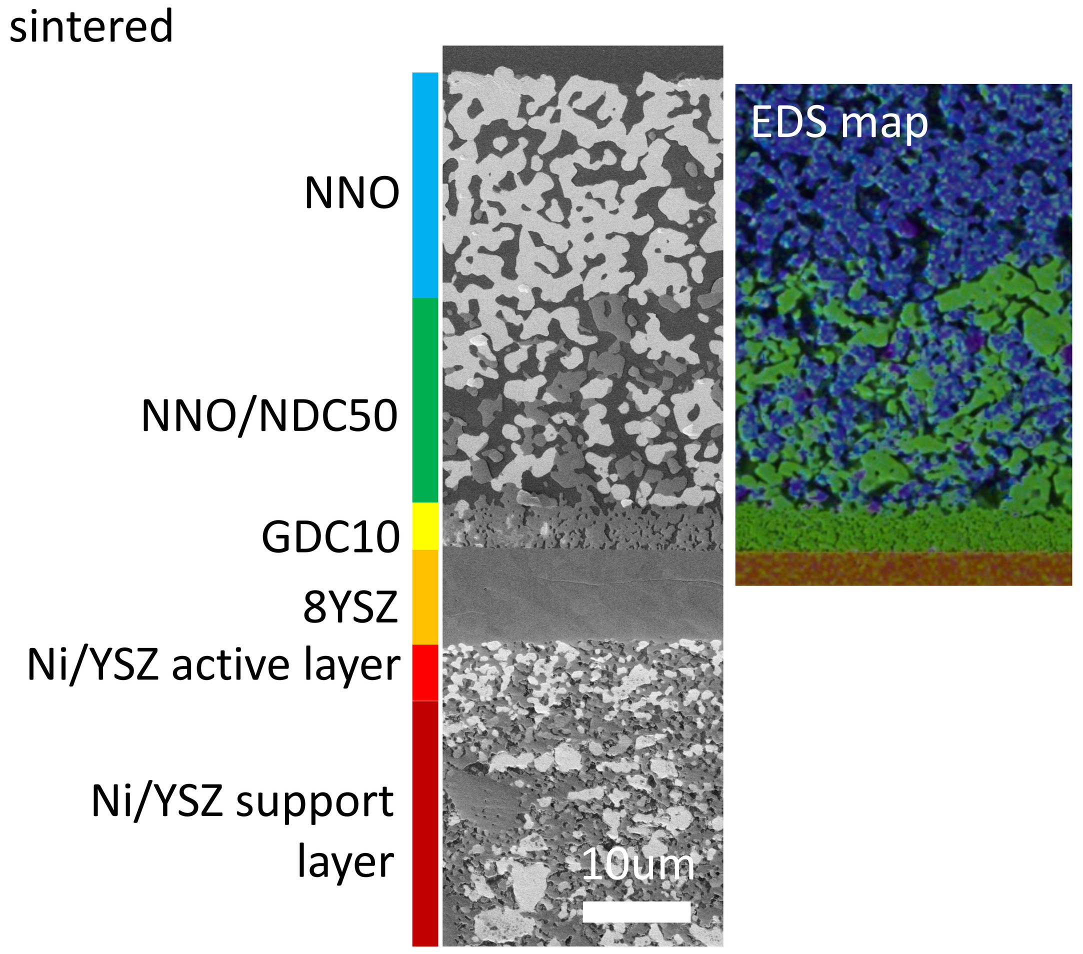
Introduction

- Reversible solid oxide fuel cells (RSOCs) are a promising technology for energy storage and production[1]
- In **electrolysis mode**, RSOCs store energy by splitting water to generate hydrogen
- To produce energy, they operate in **fuel cell mode** to convert the chemical energy of hydrogen to electricity

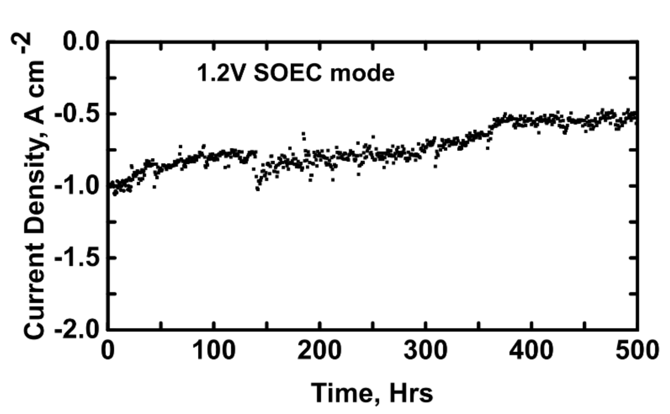
- Mitigating long-term degradation in RSOCs is critically important to expanding their viability
- **Goal: quantify the relationship between performance degradation and microstructural evolution**

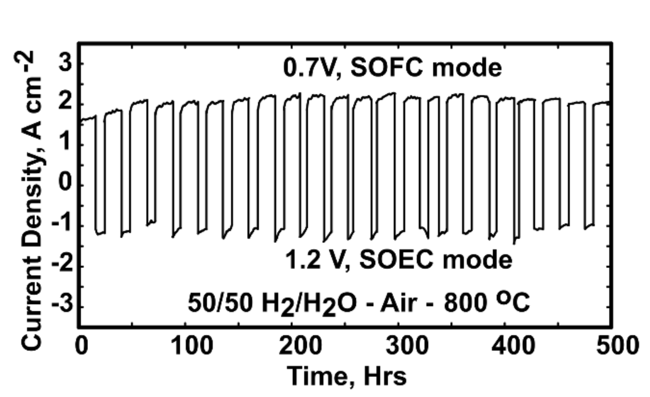
Cell Fabrication and Testing

- 8YSZ, GDC10, NNO/NDC50 and NNO were screen printed onto commercially-purchased substrates and sintered



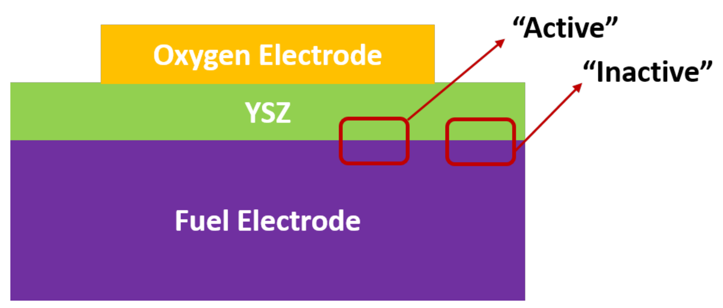
- Cells were tested in either electrolysis (SOEC) or reversible (RSOC) mode for 500hrs
- AC impedance spectroscopy and V-j scans were used to characterize the cell performance as a function of time



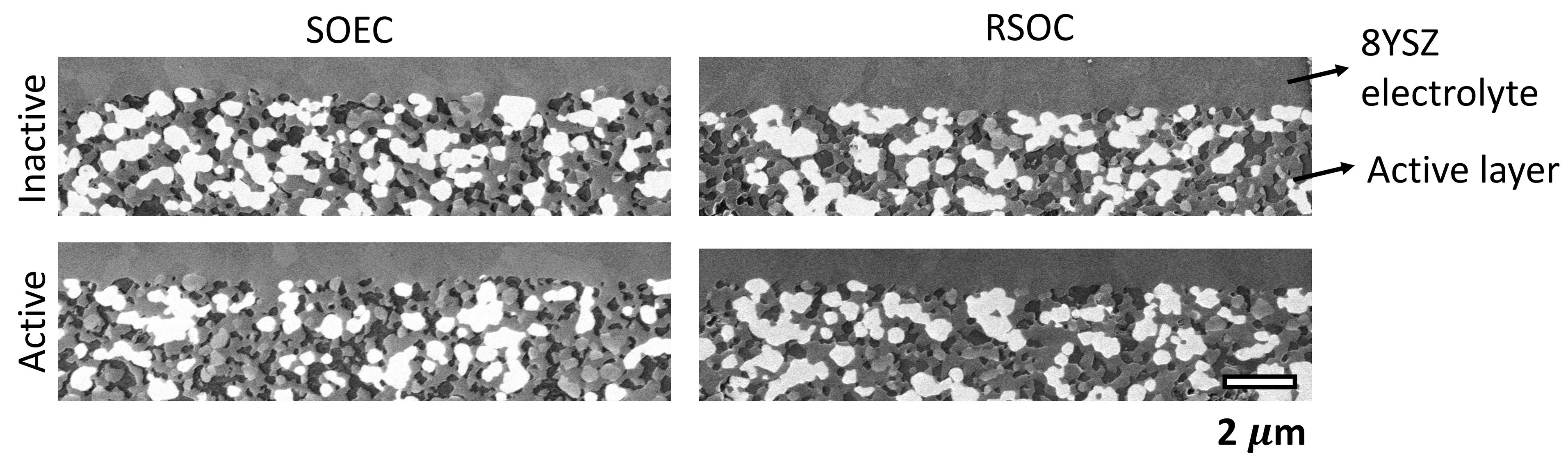


Quantifying Microstructure Evolution

- Microstructure evolution in the fuel electrode (FE) is quantified by comparing electrochemically inactive and active areas
- Low KeV imaging is used to create contrast in connected Ni particles[2]



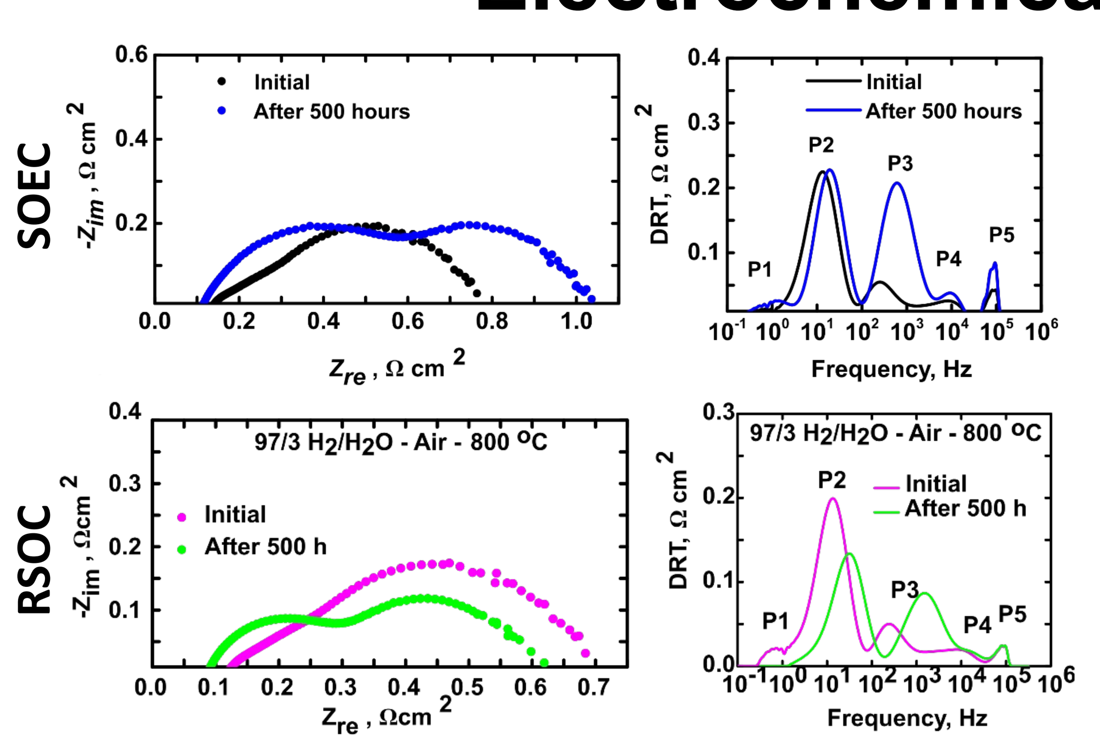
- Significant microstructure changes only occur in the hydrogen electrode over 500h—the oxygen electrode is stable at testing conditions



- Loss and coarsening of connected Ni grains is most evident with SOEC operation
- RSOC operation mitigates percolated Ni loss and coarsening, but increases porosity and pore size

Relative Changes to Inactive Region (%)	Porosity	Pore size (μm)	Connected Ni %	Connected Ni diameter (μm)
SOEC Active Layer FE	3.49	-0.14	**-8.11**	**5.35**
RSOC Active Layer FE	**5.55**	**6.79**	-2.53	2.02
SOEC Supporting Layer FE	**4.68**	2.98	-1.11	-0.41
RSOC Supporting Layer FE	2.90	-3.25	0.87	0.96

Electrochemical Results



P1: gas diffusion-limited process
P2: gas diffusion-limited process in FE
P3: O^{2-} diffusion in FE[3]
P4: TPB reaction resistance[4]
P5: ohmic resistance

- SOEC mode shows significant increase in O^{2-} diffusion resistance in FE, suggesting a loss in active sites forcing diffusion further into the FE
- RSOC mode mitigates TPB loss and improves gas diffusion-limited losses

Conclusions

- Continuous operation in SOEC mode results in significant degradation shown by DRT to be linked to the fuel electrode
- Loss of Ni connectivity in the FE active layer is identified to be a major cause of performance degradation during electrolysis
- Performance degradation was limited during RSOC operation
- Microstructural analysis shows that mode switching mitigates percolated Ni loss in the fuel electrode active layer compared to SOEC operation

- Excellent stability was observed in the oxygen electrode in both RSOC and SOEC modes of operation
- Minimal degradation is evident in the fuel electrode supporting layer, but is expected to occur over longer timescales

- **The NNO|NNO-NDC50|GDC10|8YSZ|Ni-YSZ cell architecture shows significant promise as a candidate for energy storage applications**
- **Clear microstructure/performance relationships have been established for a limited-duration test**

Selected Citations and Acknowledgements

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