Design and fabrication of high-performance thin film SOFCs

Verweij.1@osu.edu
mse.osu.edu/faculty/verweij

K. Shqau, F. M. Zalar and H. Verweij

Materials Science & Engineering dept
2041 College Road
Columbus OH 43210-1178, USA

Introduction

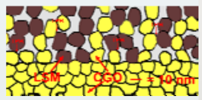
Solid Oxide Fuel Cells (SOFC) convert the free enthalpy of a combustion reaction into electric energy. State-of-the-art SOFC is made by tape casting, screen printing and sintering at ~1400°C. The results in less than ideal performance due to resistive and surface transfer losses; thermo-chemical degradation occurs by residual thermal expansion mismatch. We address this by design, realization and characterization of active thin films SOFCs on a macro-porous α-Al_2O_3 carrier. This minimizes losses and alleviates thermal expansion restrictions. Detailed modeling of SOFC transport processes, based on simple, consistent reversible and irreversible thermodynamic descriptions can leads to an optimized cell design.

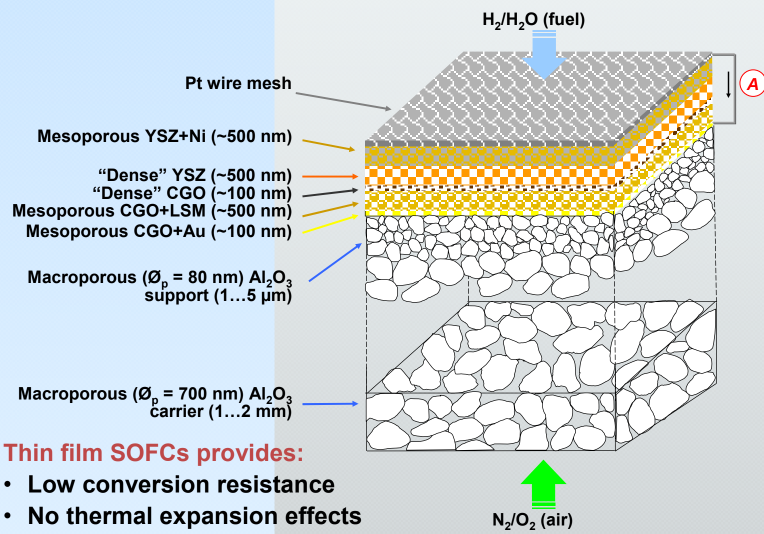
Objectives

- **Synthesis of high performance supported thin film SOFC**
- **Continuum modeling of simplified SOFC geometries.**
- **Characterization in terms of minimal parameter set.**
- **Iterative development of improved designs.**

Methods

Concept stable supported thin SOFCs:





Thin film SOFCs provides:
- **Low conversion resistance**
- **No thermal expansion effects**
- **Viable rapid manufacturing**

Requires:
- **Composite electrodes**
- **Reaction buffers**
- **High purity colloids**
- **Control by stability, rheology**

Macro-porous α-Al_2O_3 carrier for:
- **Smooth deposition surface**
- **Mechanical strength**
- **Thermal conductivity**
- **Gas permeability**

Modeling continuum (ir)reversible thermodynamics:

Onsager **transport:** $j_{O^{2-}} = -c_{O^{2-}} b_{O^{2-}} \nabla \tilde{\mu}_{O^{2-}}$

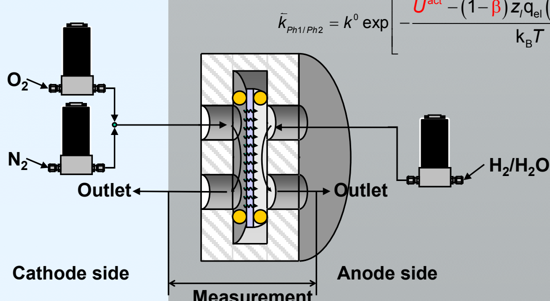
Poisson: $\nabla \cdot [\varepsilon(x) \nabla \Phi(x)] = -\rho_Q(x)$

Langmuir **chemical potential:** $\tilde{\mu}_{O^{2-}} = \mu^0_{O^{2-}} + k_B T \left[\ln \left(\frac{\theta_{O_O}(x)}{1-\theta_{O_O}(x)} \right) \right] + z_{O^{2-}} q_{el} \Phi(x)$

Butler-Vollmer **interface transfer:** $j_{O^{2-},\,Ph1/Ph2} = \bar{c}^0_{Ph1/Ph2} \left[\vec{k}_{Ph1/Ph2} \theta_{O_O,Ph1} \left(1-\theta_{O_O,Ph2}\right) - \overleftarrow{k}_{Ph1/Ph2} \theta_{O_O,Ph2} \left(1-\theta_{O_O,Ph1}\right) \right]$

$$\vec{k}_{Ph1/Ph2} = k^0 \exp\left[-\frac{U^{act} - (1-\beta) z_i q_{el} \left(\Phi_{Ph2} - \Phi_{Ph1}\right)}{k_B T} \right]$$

IV and EIS characterization:

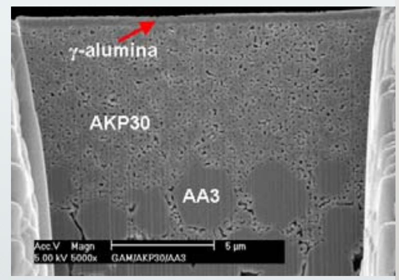


Conclusions

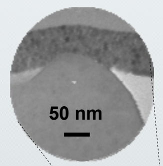
- **Sequence of homogeneous thin supported films deposited.**
- **Finite element modeling (non-)linear response simple structure.**
- **Characterization set-up is available.**

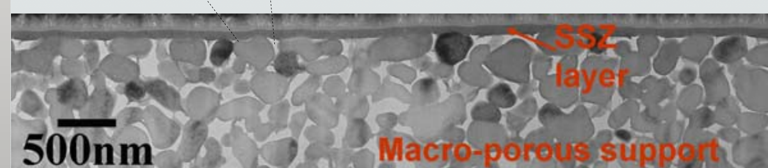
Results

Colloidal deposition:

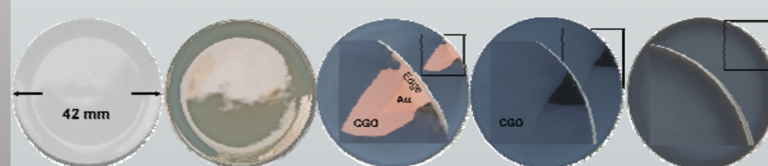


Multi-layer alumina support



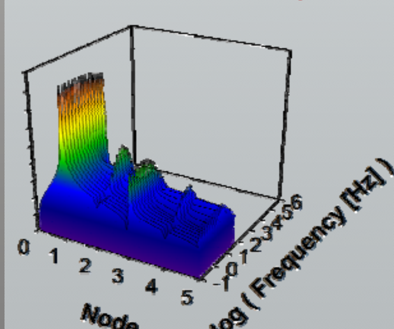


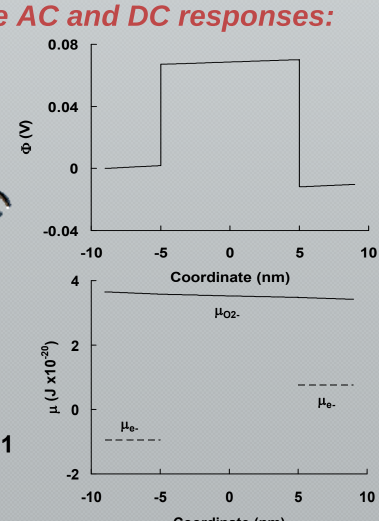
Deposition of 3 nm Ø SSZ particles, drying, sintering at 600°C



Alumina support, +Au, +CGO+LSM, +CGO, +YSZ

Finite element steady state AC and DC responses:





(Non-)harmonic responses:
- **Simulated asymmetric cell**
- **Generally <4 parameters node 1**
- **More parameters nodes >1?**

Steady state DC potentials

Acknowledgement

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