Novel Cathodes Prepared by Impregnation Procedures

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Yingyi Huang, Raymond Gorte, John Vohs
University of Pennsylvania

Naiffer Romero, Wayne Gardner, Eduardo Paz
Franklin Fuel Cells, Inc.

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POC: Eduardo Paz, epaz@franklinfuelcells.com, (610) 640-7545

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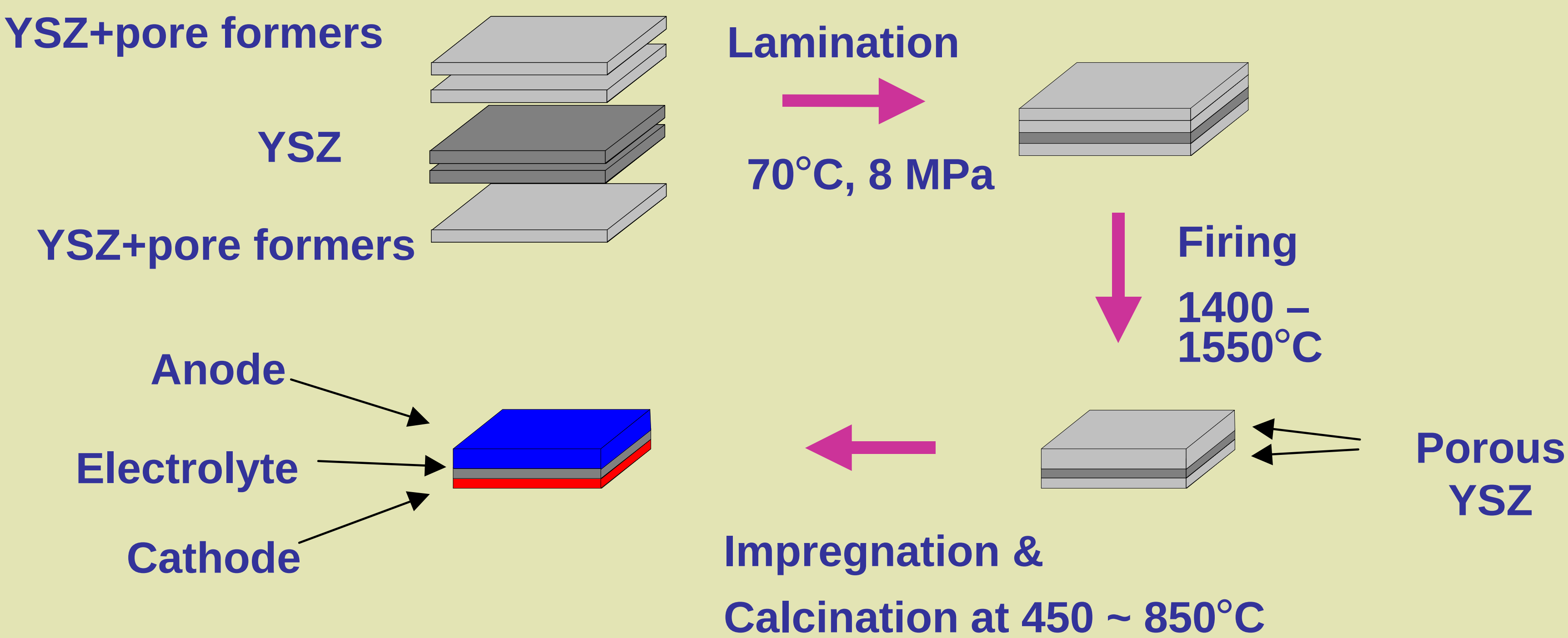
Technical Issues

- LSM / YSZ cathodes are widely used but exhibit only modest performance at 700°C and are impractical for operation at lower temperatures
- More conductive cathode materials are available but …
  - High temperature calcination necessary to sinter YSZ causes solid state reactions
  - Doped ceria interlayers often used to avoid solid state reactions are not always effective
  - Poor CTE match between these “improved” cathodes and YSZ can hurt cell lifetime

R&D Objectives & Approach

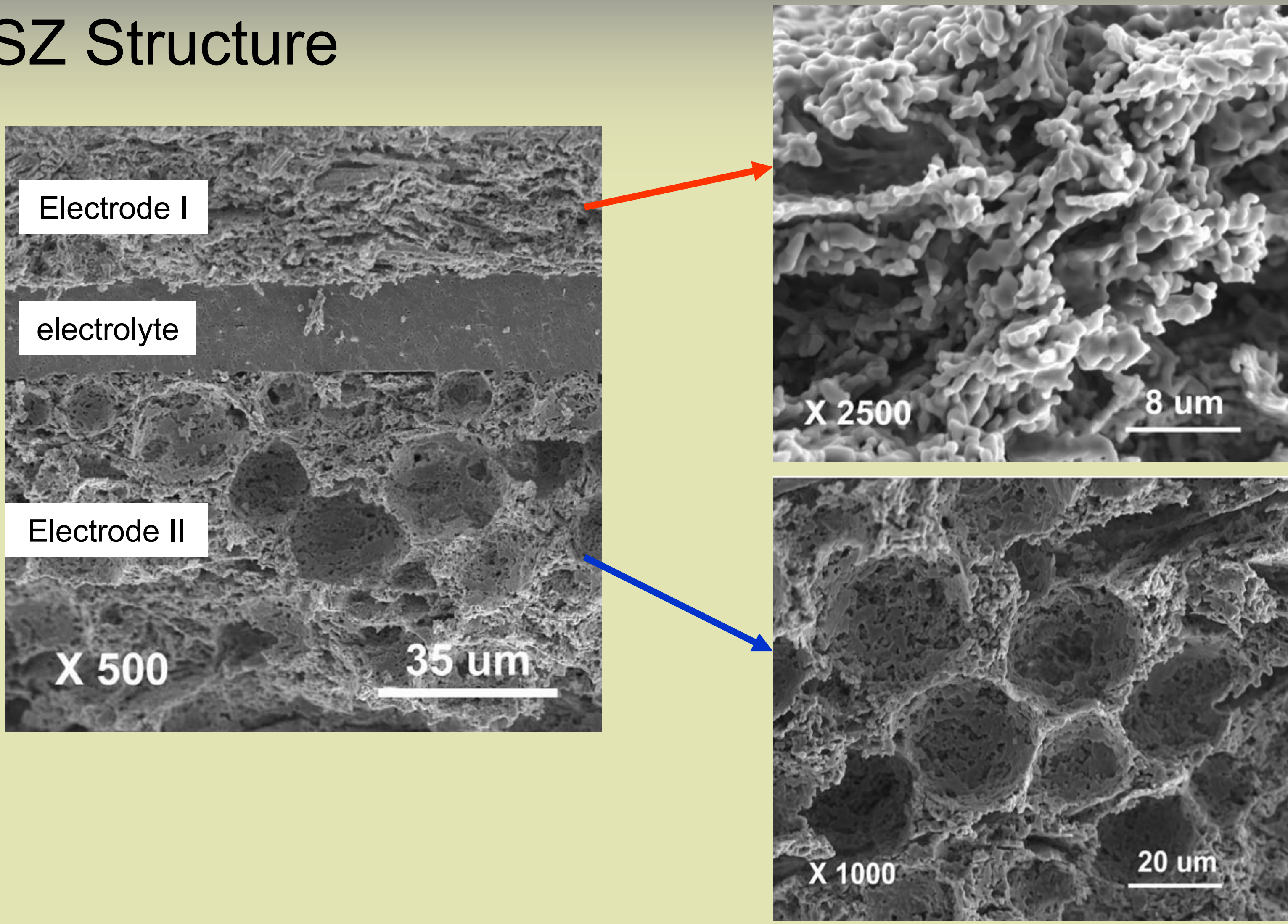
Approach

– Impregnate perovskite into a porous matrix of YSZ that has already been sintered to high temperatures



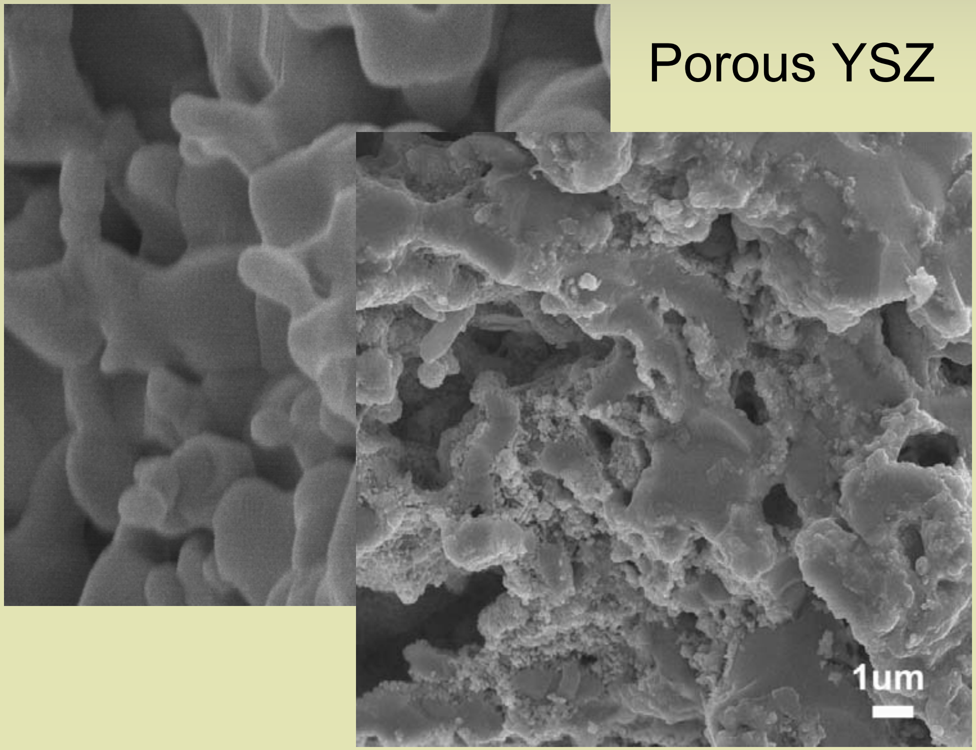
R&D Objectives & Approach

YSZ Structure



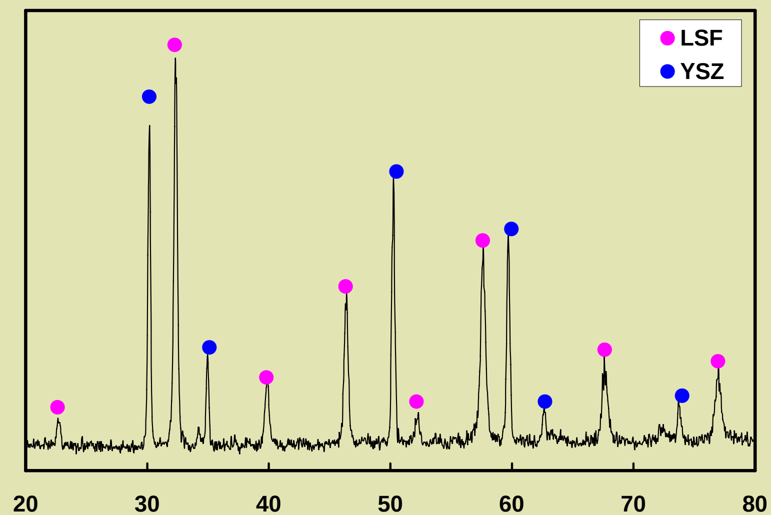
R&D Objectives & Approach

Infiltrate with metal salts or perovskite nanoparticles



Porous YSZ

40 wt% LSF-YSZ by impregnation



XRD after calcination to 850°C

Correct phases are formed

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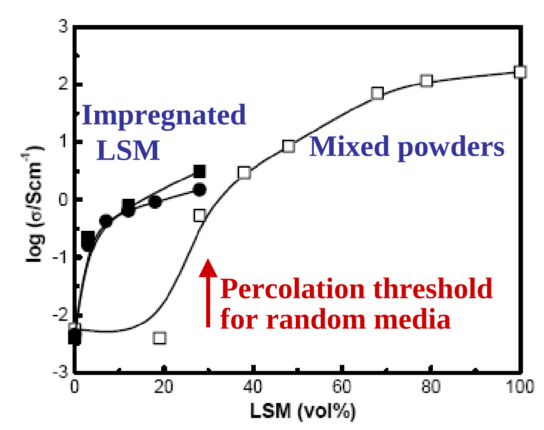
R&D Objectives & Approach

Advantages

- Separate firing temperatures for YSZ and perovskite.
  - Avoids solid-state reactions between LSF & YSZ.
- Composite is non-random structure; perovskite coats pores.
  1. Electrical conductivity of LSM-YSZ

     700ºC in air, composites calcined at 1523 K.



  2. CTE of LSCo-YSZ (CTE of LSCo is 23x10-6/K)

LSCo Weight Fraction in YSZ	0%	35%	45%	55%
CTE (10^{-6}/K), 300 to 1073 K	10.3	11.7	12.6	12.6

R&D Objectives & Approach

Project Objectives

- Compare key performance attributes (power density / ASR, lifetime effects, cost) for the following three cathode systems:
  - Paste LSM
  - Impregnated LSM
  - Impregnated LSF
- Evaluate ways of improving impregnation process
  - Nanosized perovskite colloidal dispersion
  - Molten salt

Key Technical Risks

- Potential for long term operation to result in the formation of insulating phases leading to decreased performance
- Sintering of perovskite particles that reduces performance or requires significantly heavier loadings

Accomplishments

- Two 1000 hour tests of impregnated LSF working cells show nearly flat performance
- Symmetric cell tests for impregnated LSF-YSZ and LSCo-YSZ electrodes show phenomenal performance, as low as 0.1 Ωcm^2 and 0.03 Ωcm^2 at 700°C in air
- LSF-YSZ and LSCo-YSZ cathode supported cells tested, yielding similar performance to anode supported cells
- Impregnated anode supported LSM-YSZ cells tested show similar performance to that of conventional paste LSM-YSZ cells
- Molten salt impregnation of LSM shown to reduce infiltration steps by factor 2

Phase I Project Plan

Task 1 – Cost Analysis

– Cost models for paste LSM, infiltrated LSM and infiltrated LSF

Task 2 – Characterize Baseline Design

– Long run testing and material characterization of paste and impregnated cells

Task 3 – Improvement of Design

– Evaluate higher perovskite loadings and / or use of mixed perovskites

– Long run testing and material characterization of paste and impregnated cells

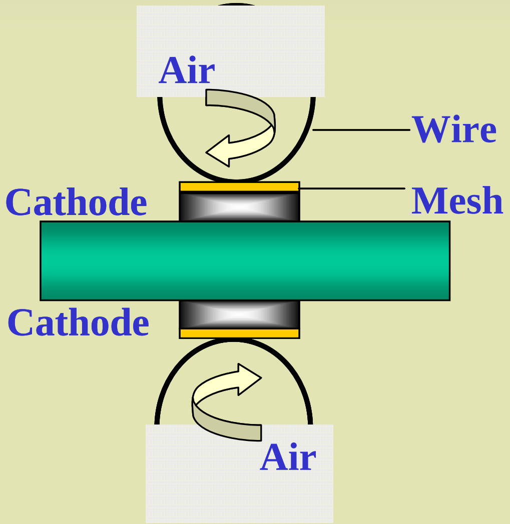
Task 4 – LSM Nanoparticle Proof of Concept

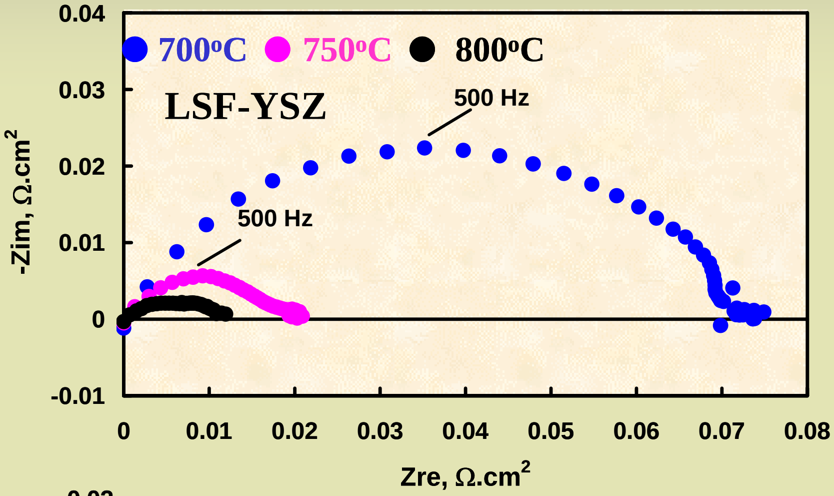
– Synthesis of nanoparticle LSM colloidal dispersion

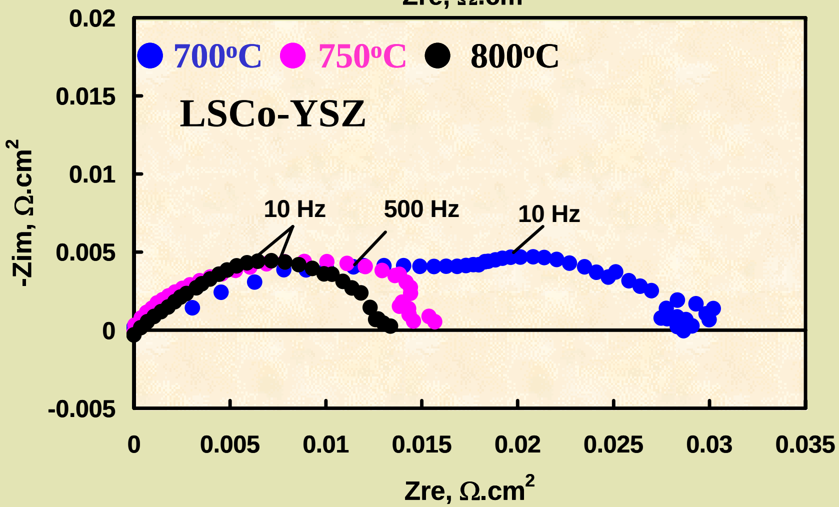
– Working cell testing of impregnated nanoparticle LSM cells

Results to Date

Symmetric cell testing of LSF-YSZ AND LSCo-YSZ







Good agreement with fuel cell data!

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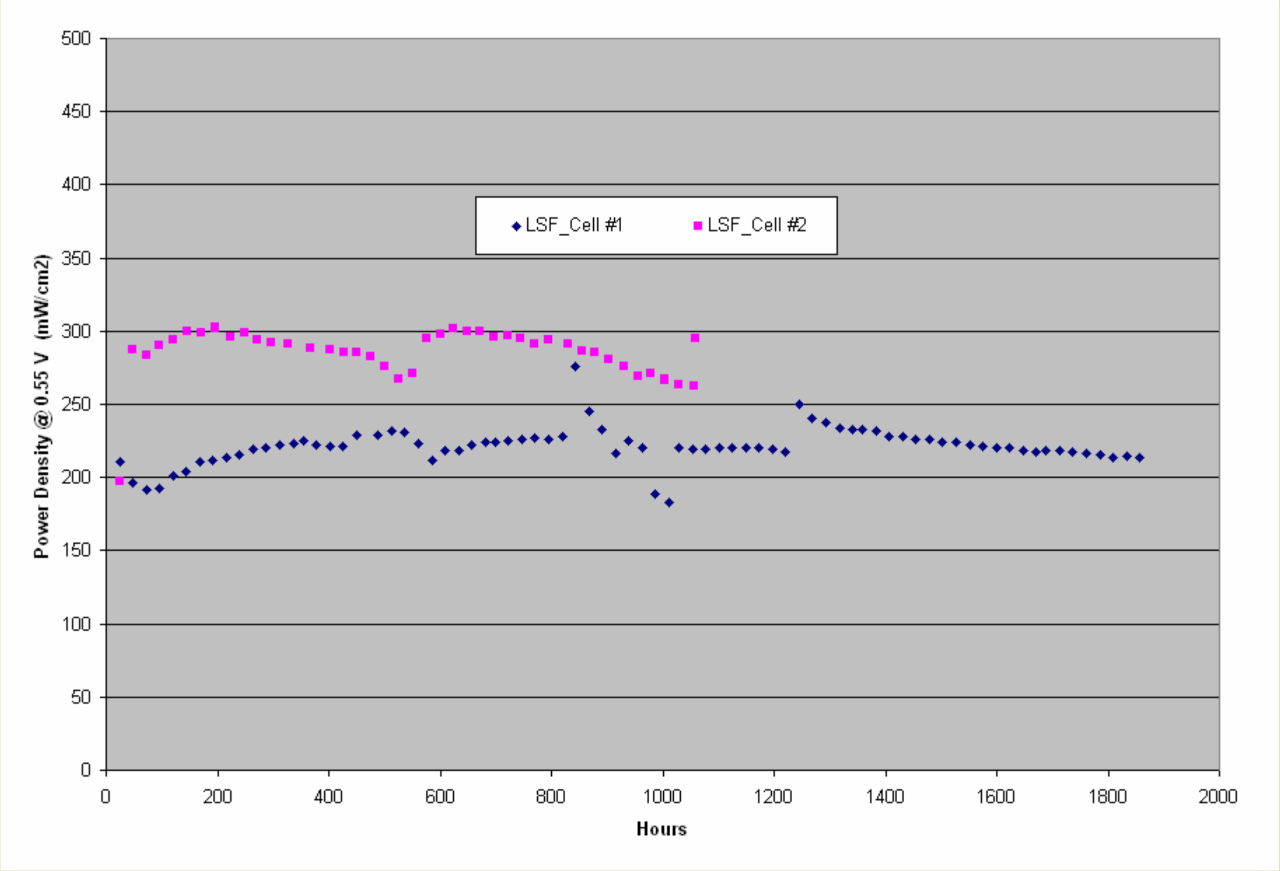
Results to Date

Long run tests of infiltrated LSF-YSZ working cells at 700°C



Anode: Cu-CeO_2 / 8YSZ
Electrolyte: 45 -60 µm 8YSZ
Cathode: LSF / YSZ

Fuel: H_2 (3% H_2O)

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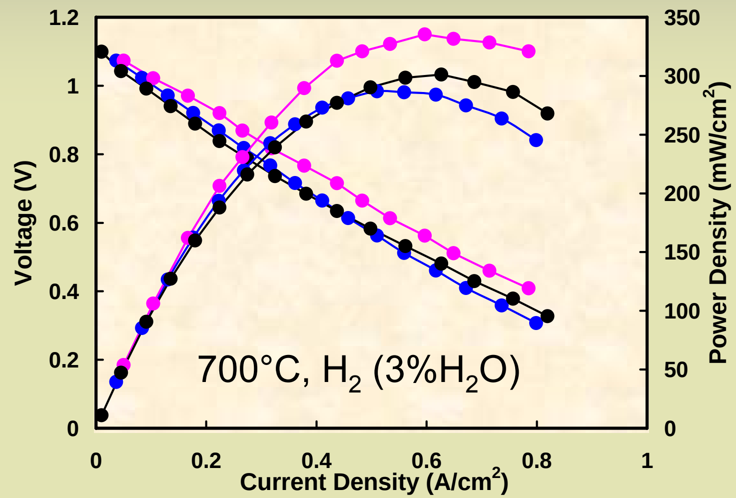
Results to Date

- Impregnation of LSM in YSZ using
  - Nano-particles (•)
  - Aqueous solutions (•)
  - Molten salts (two steps) (•)



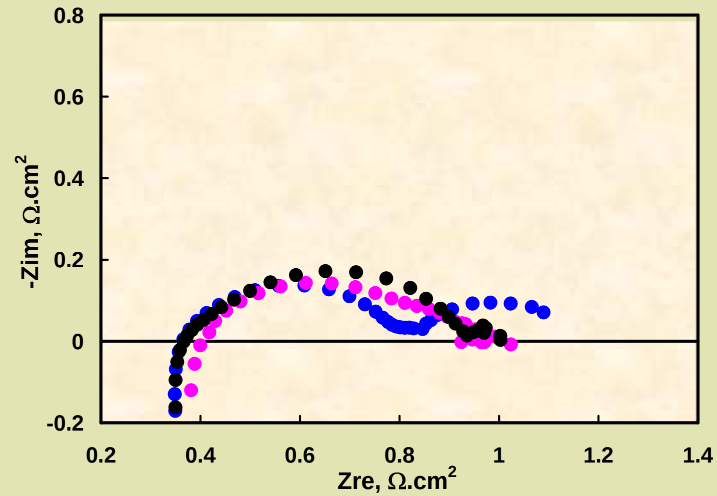
Cathodes calcined at 1050°C

Anode: Co-CeO2

Electrolyte: 60 µm

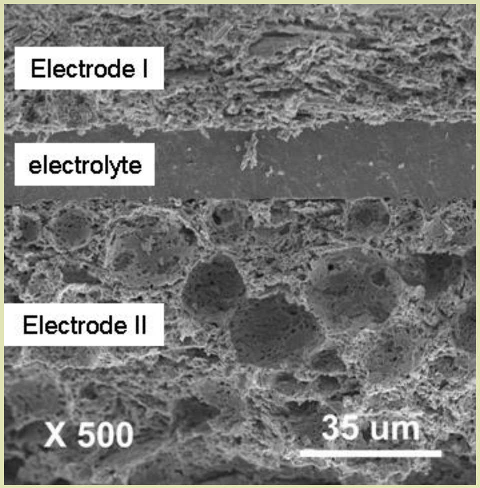
Cathode: LSM-YSZ

Fuel: H2 (3%H_2O)



Results to Date

Cathode Supported Cells



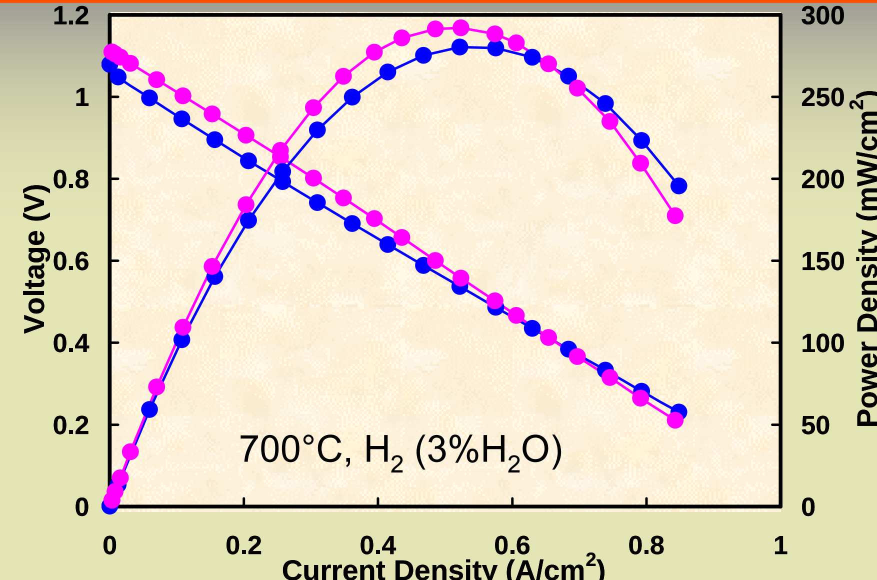
Electrode I: 60 µm

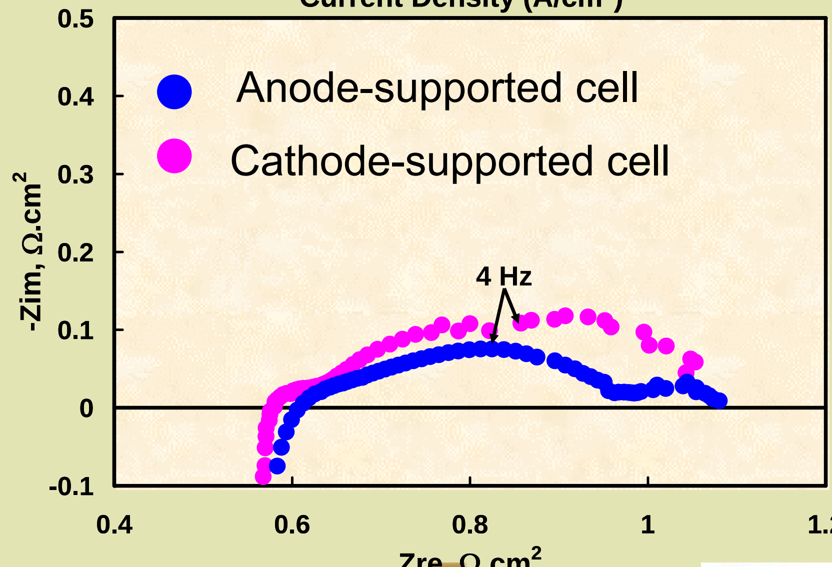
Electrolyte: 60 µm

Electrode II: 600 µm

Cathode: LSF-YSZ

Anode: Cu-Ceria-YSZ





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Applicability to SOFC Commercialization

- Method may allow the use of more conductive cathode materials that, in turn, permit lower temperature operation and / or higher power density and lower system cost
- Ability to produce high performance cathode supported cells
- Fabrication of impregnated cathodes is compatible with most types of SOFCs currently used by industrial teams

Next Steps

- Develop cost models
- Material characterization of long run cells
- Evaluate increased perovskite loading
- Evaluate improved impregnation methods

Thank You

Contact:
Eduardo Paz
epaz@franklinfuelcells.com
(610) 640-7545

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