

Intermediate Temperature SOFC

Ceramatec, Inc. (Dr. S. Elangovan)

Caltech (Dr. Sossina Haile)

Northwestern University (Dr. Scott Barnett)

SECA Core Technology Program Review

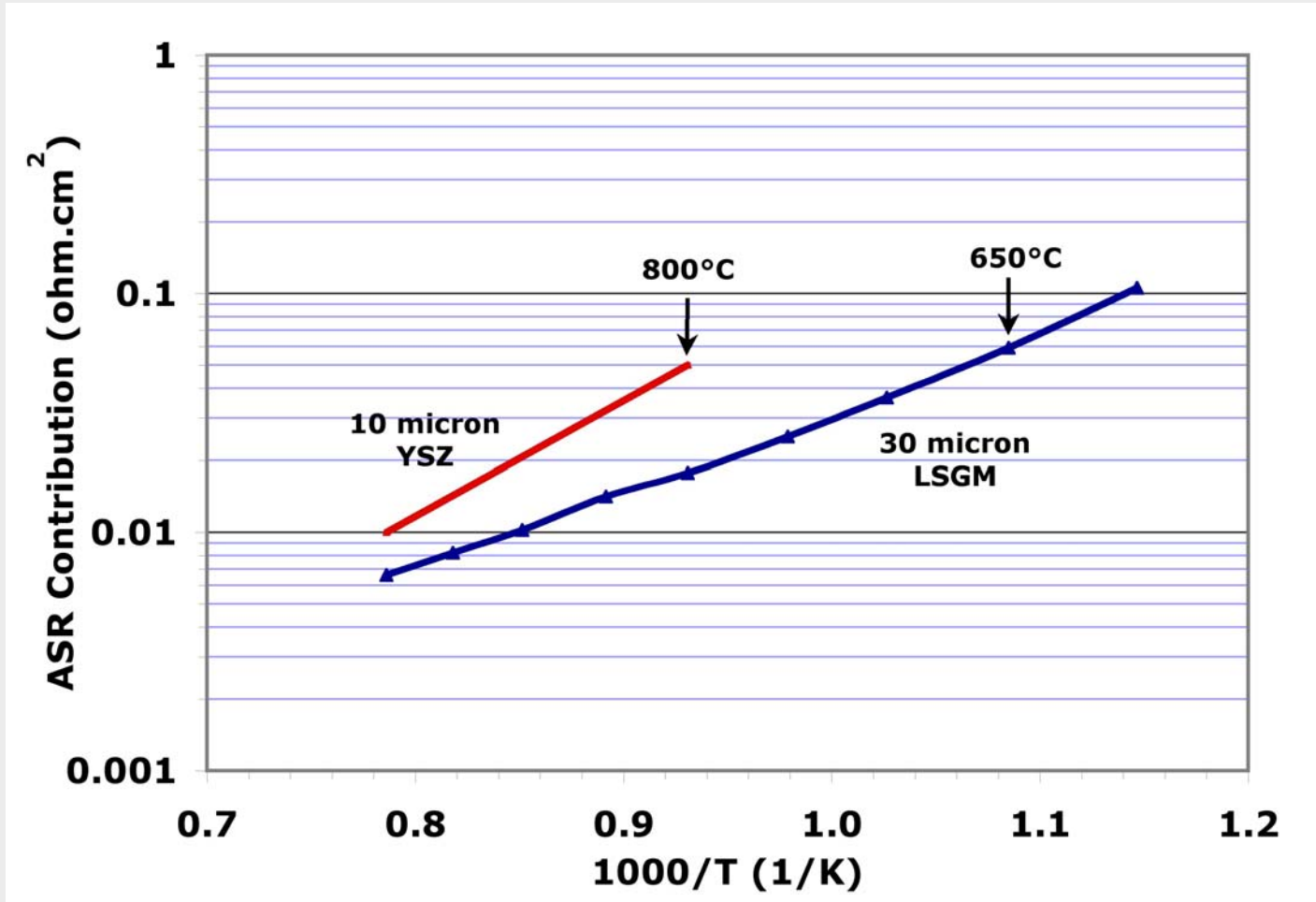
Philadelphia, PA

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Conductivity Comparison: LSGM and YSZ Electrolyte

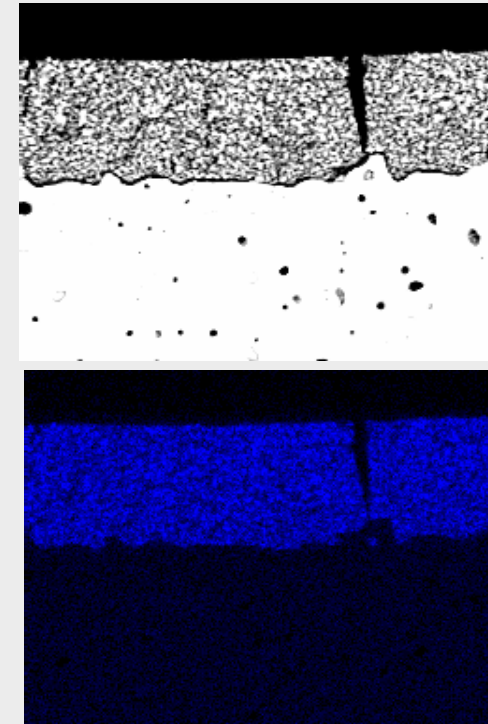
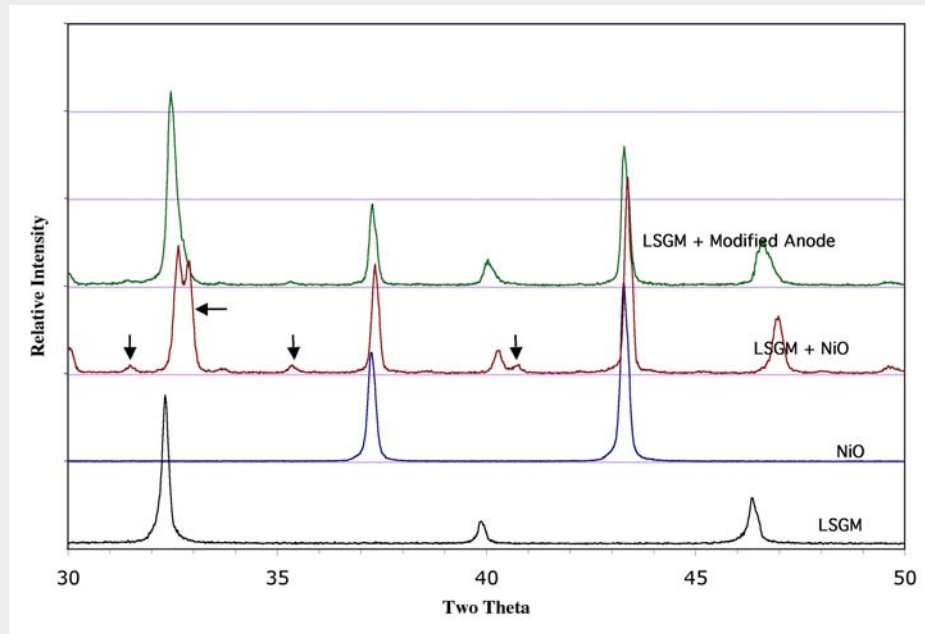


Benefits of LSGM Electrolyte

- **Stability in SOFC environment (air and fuel pO_2)**
 - Ionic transference number ~ 1
- **Potential for 650°C operation**
 - Conductivity comparable to YSZ at 800 - 850°C
 - Compatibility with perovskite cathode
 - Cobaltite based material is a good cathode
 - Metal interconnect challenges are reduced
 - Lower system cost
 - 650 - 700°C operation well-suited for partial internal reformation; offering a significant reduction in heat exchanger requirement

Anode material compatibility

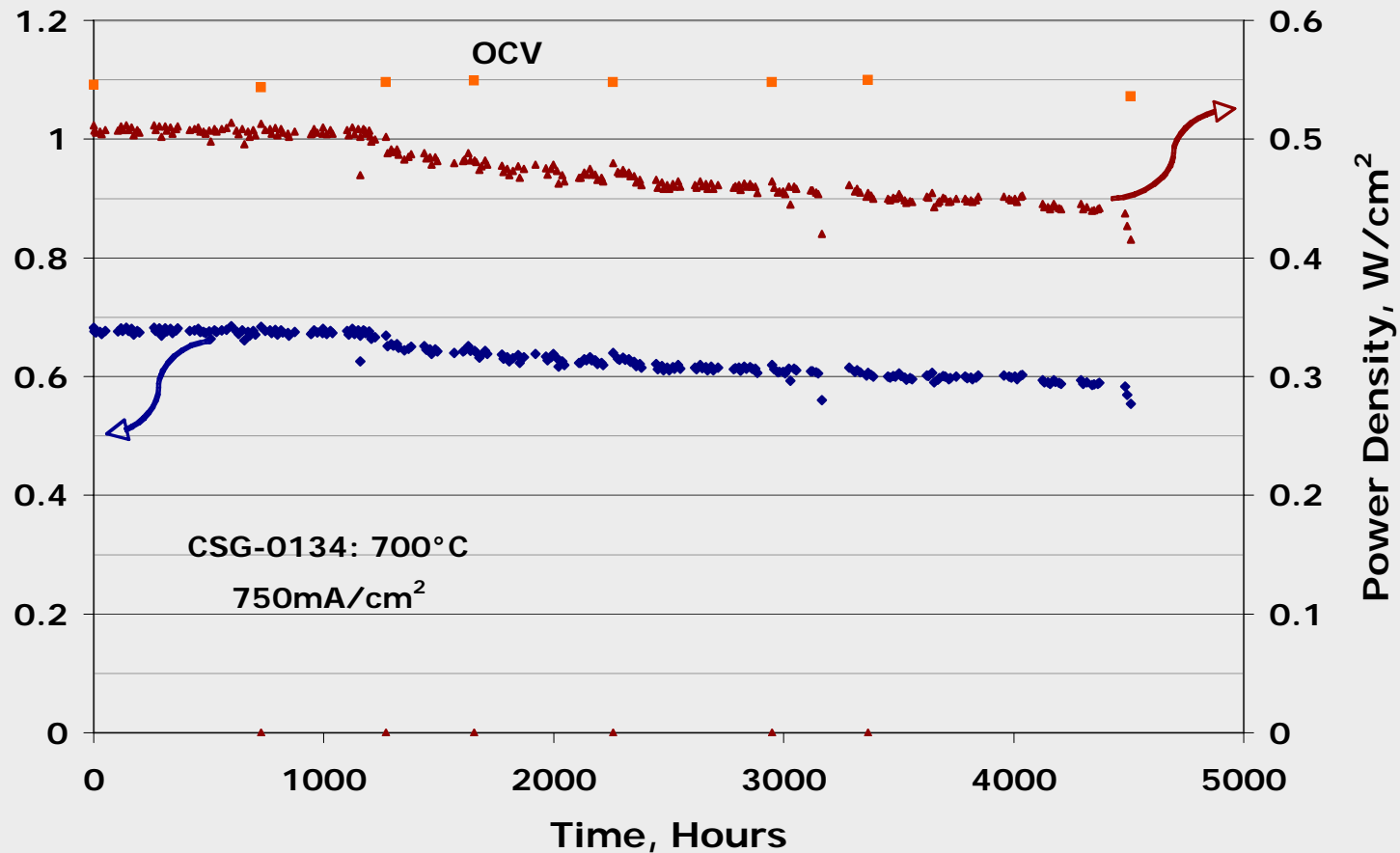
- Reduce Ni reaction with modified anode composition



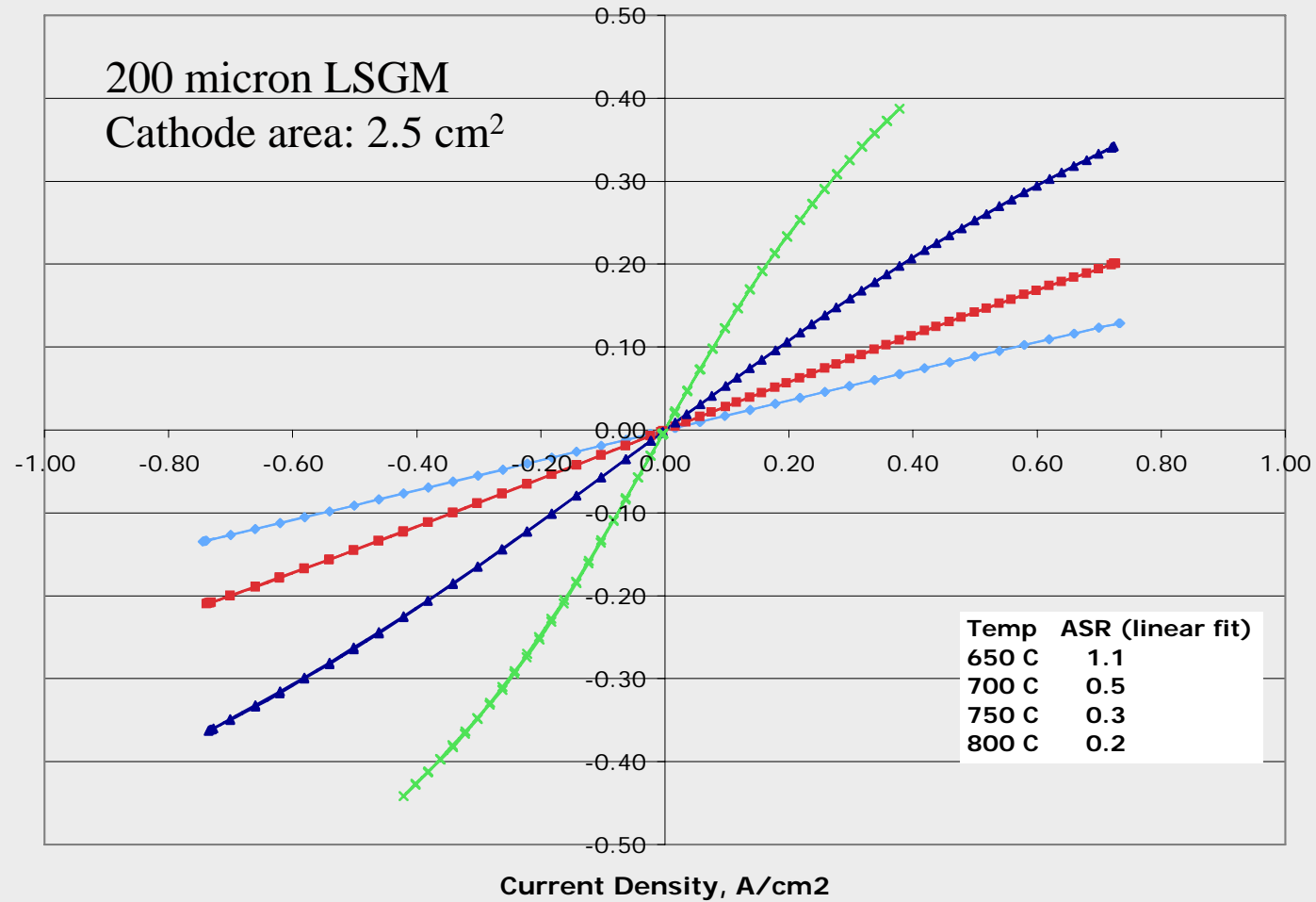
- Powder mixture (LSGM + modified anode) calcination at 1350°C for four hours
- SEM and Ni map after 1,200 hours of cell operation

Single cell stability

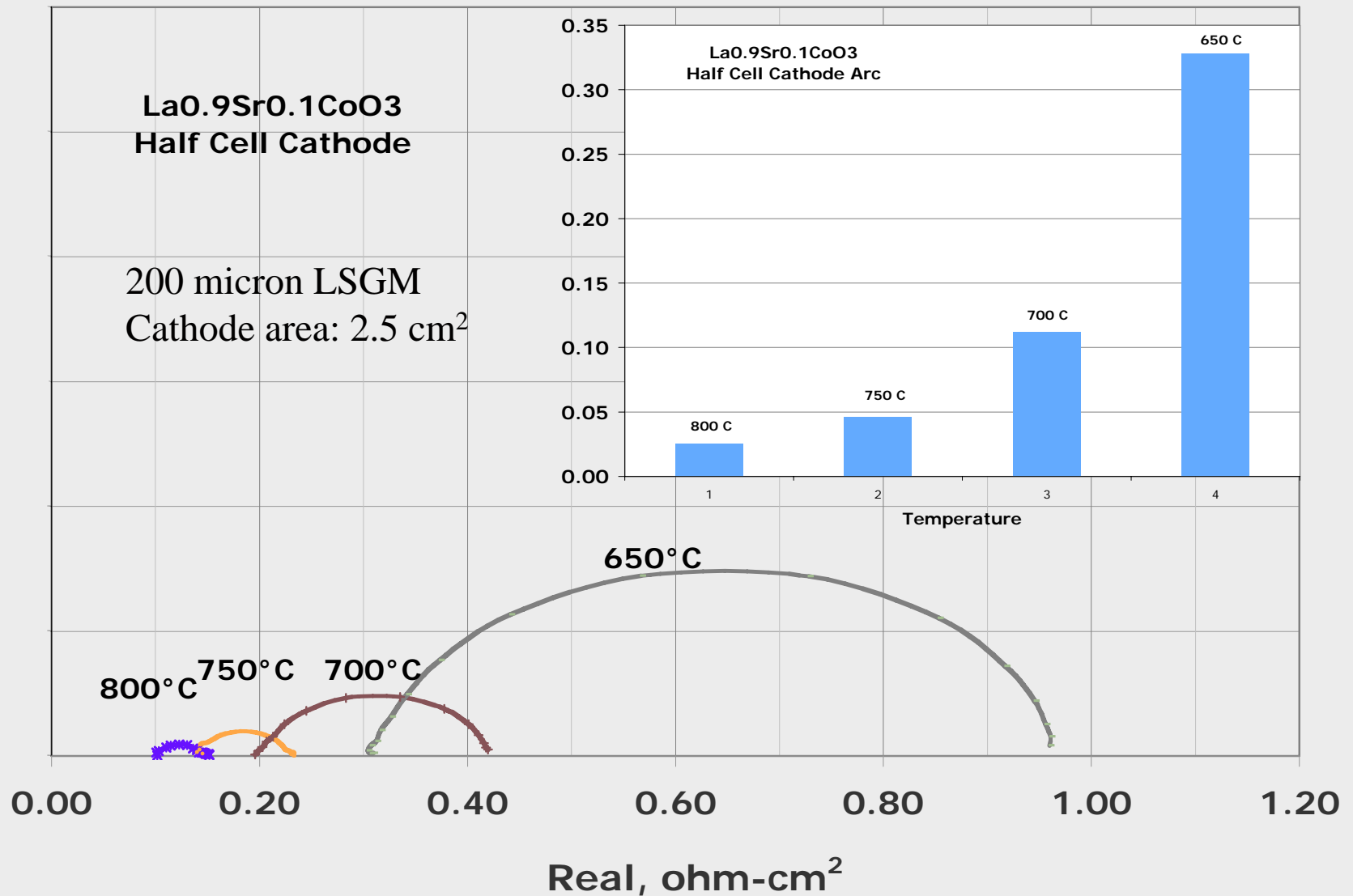
- ASR at 700°C with thin LSGM supported on cathode structure: $\sim 0.5 \text{ ohm.cm}^2$



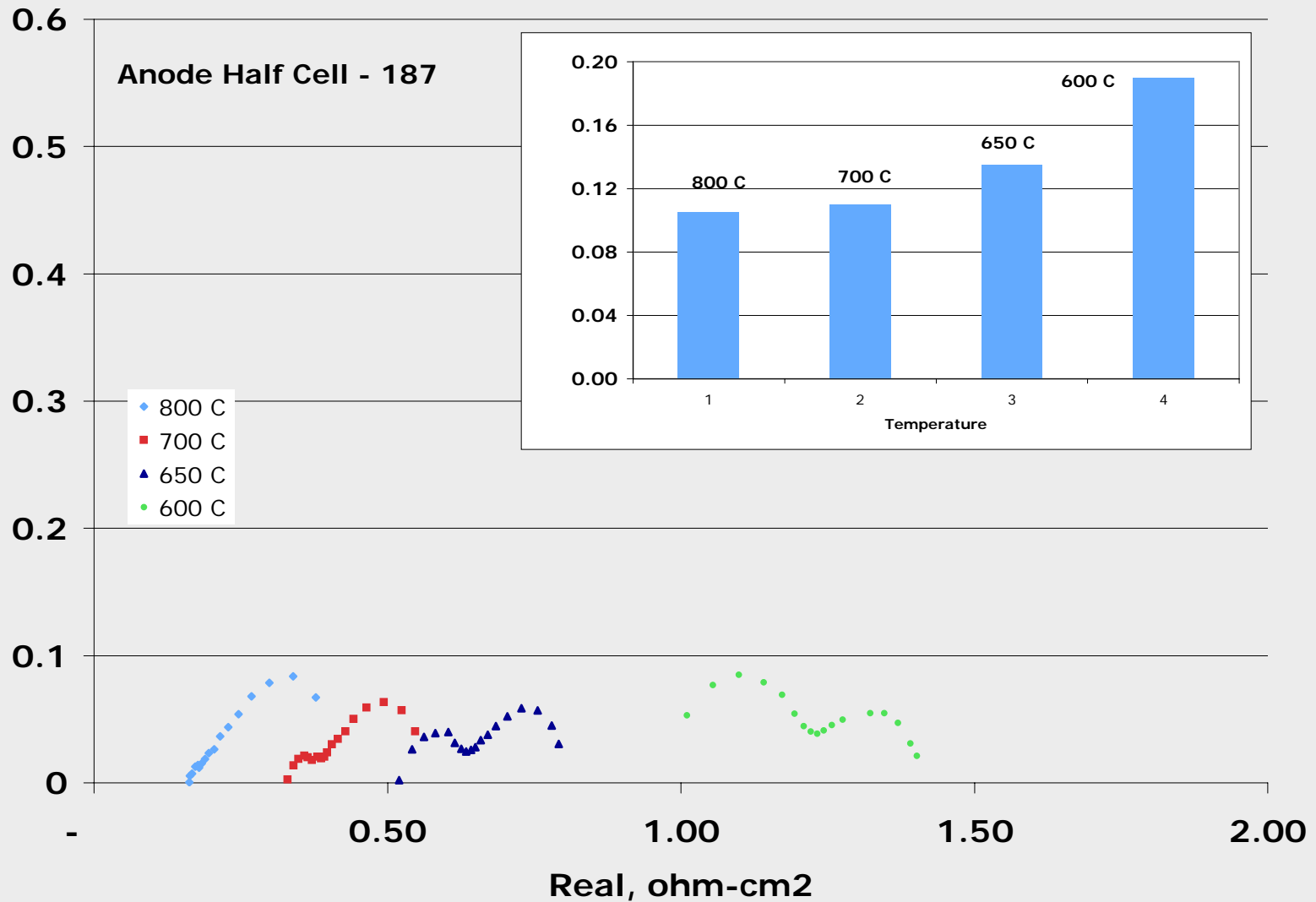
Cathode half cell DC



Cathode half cell AC

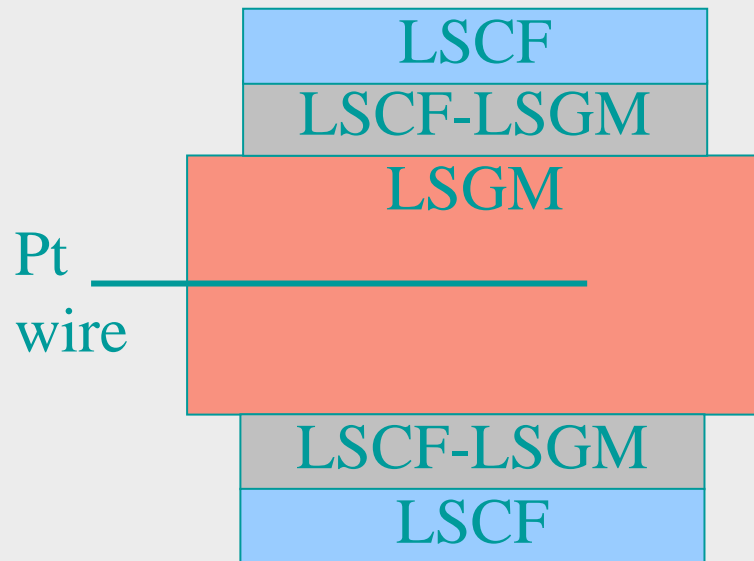


Anode half cell AC





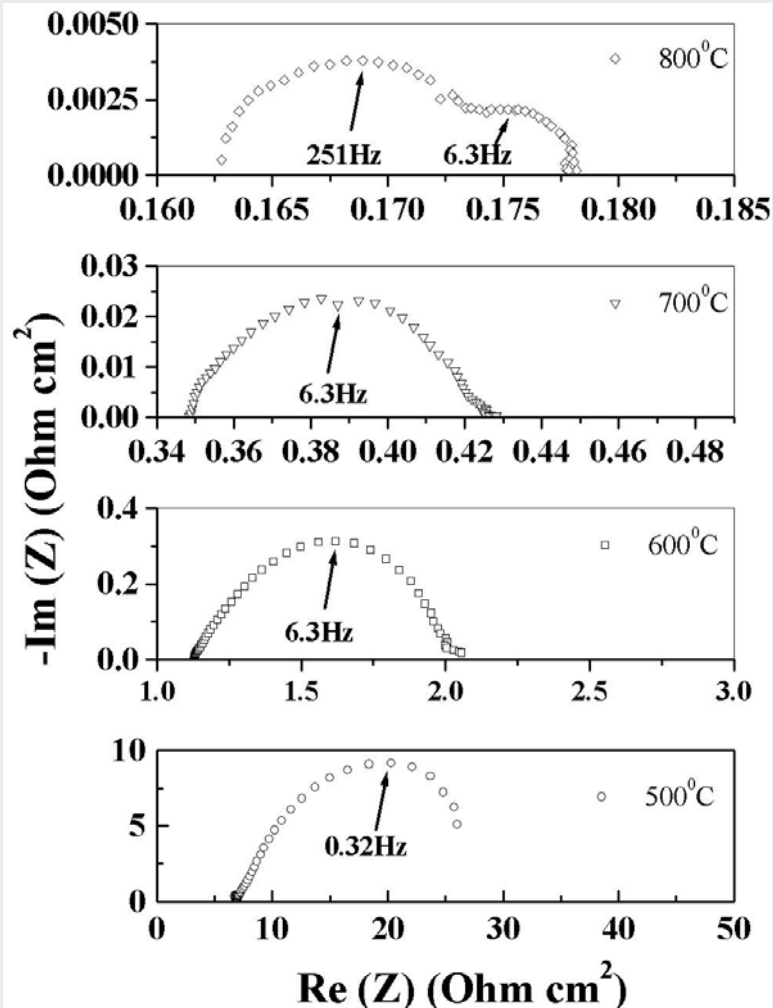
LSCF-LSGM Cathode Study



- **Aim:** Explore utility of LSCF-LSGM for reduced-temperature (~650C) LSGM electrolyte SOFCs
- **Methodology**
 - Screen printed layers
 - Fired at 1100C
 - Symmetric samples
 - Thick LSGM electrolytes
 - LSCF current collectors and Ag contacts/wires
 - Embedded Pt reference electrode
 - Electrochemical impedance spectroscopy (EIS) measurements



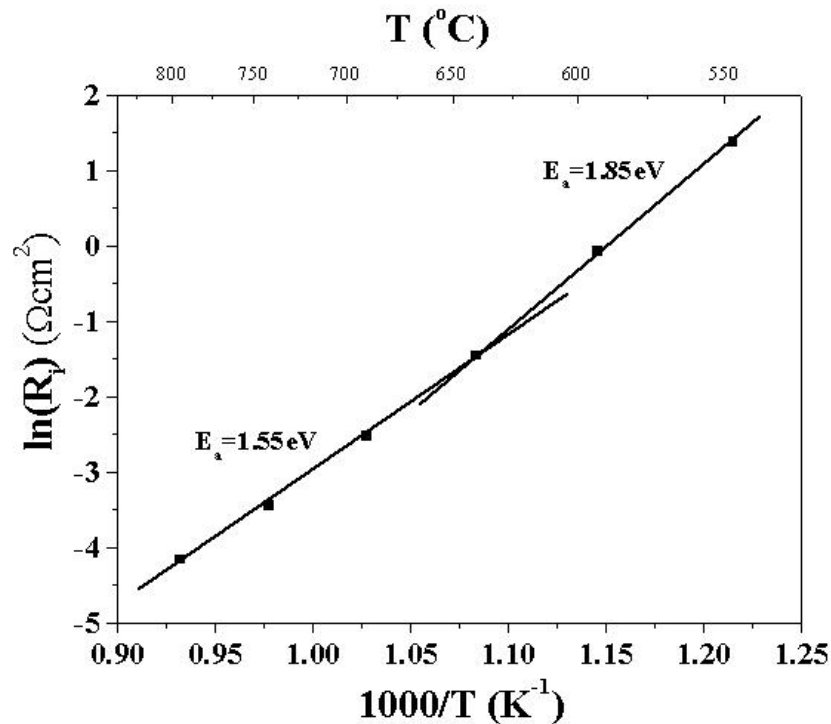
Typical EIS Data



- **Measurement**
 - In air, versus temperature
 - Zero dc current
- **Apparent single arcs except at 800C**
- **Low polarization resistance above ~600C**



Temperature Dependence

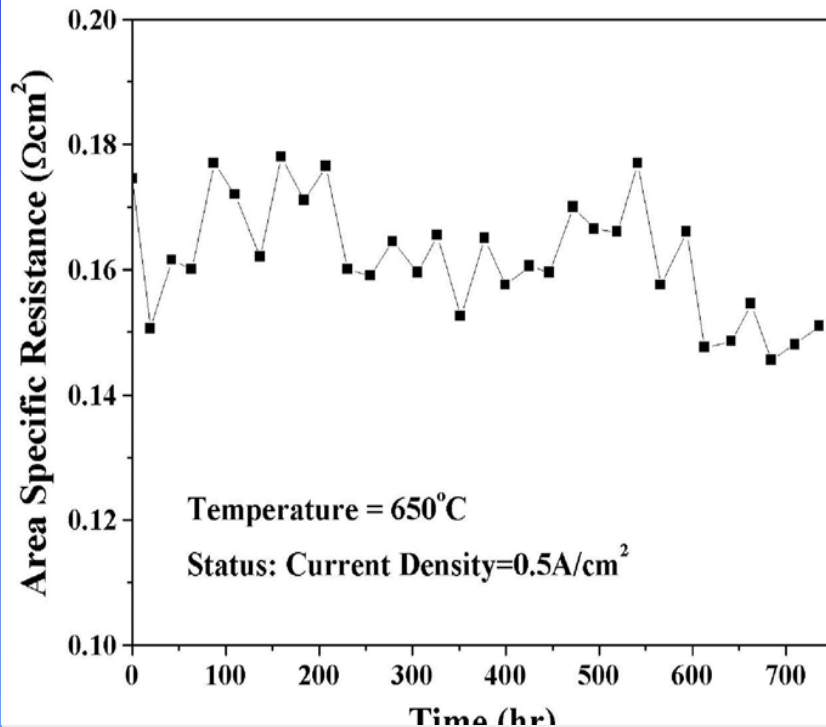


- Derived from EIS spectra above
- Strong temperature dependence
 - Activation energy ~ 1.6 eV similar to prior reports on LSCF-GDC

Life Test



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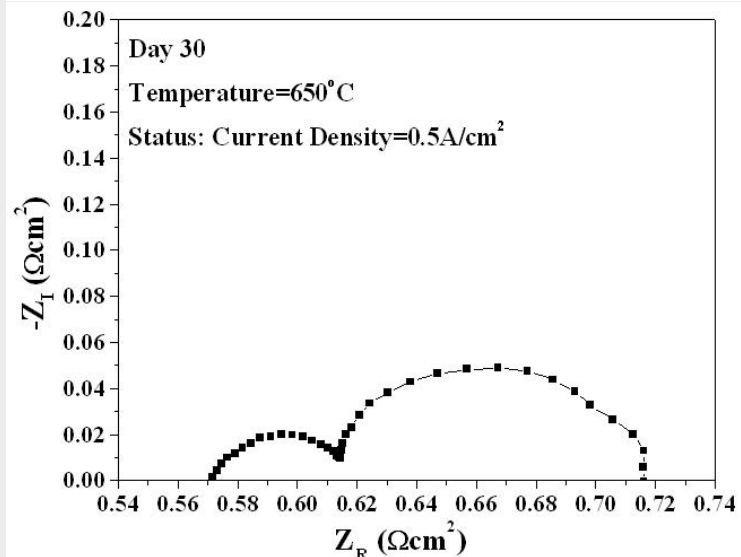
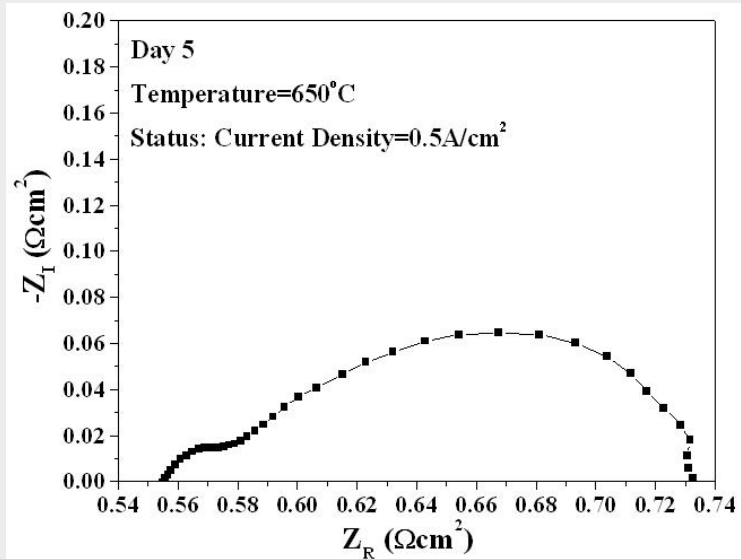


- **750 h test**
 - 650C
 - 0.5A/cm²
- **Plot shows total electrode arc width**
 - EIS measured at zero dc current
- **Stable within experimental accuracy**

EIS Spectra During Life Test



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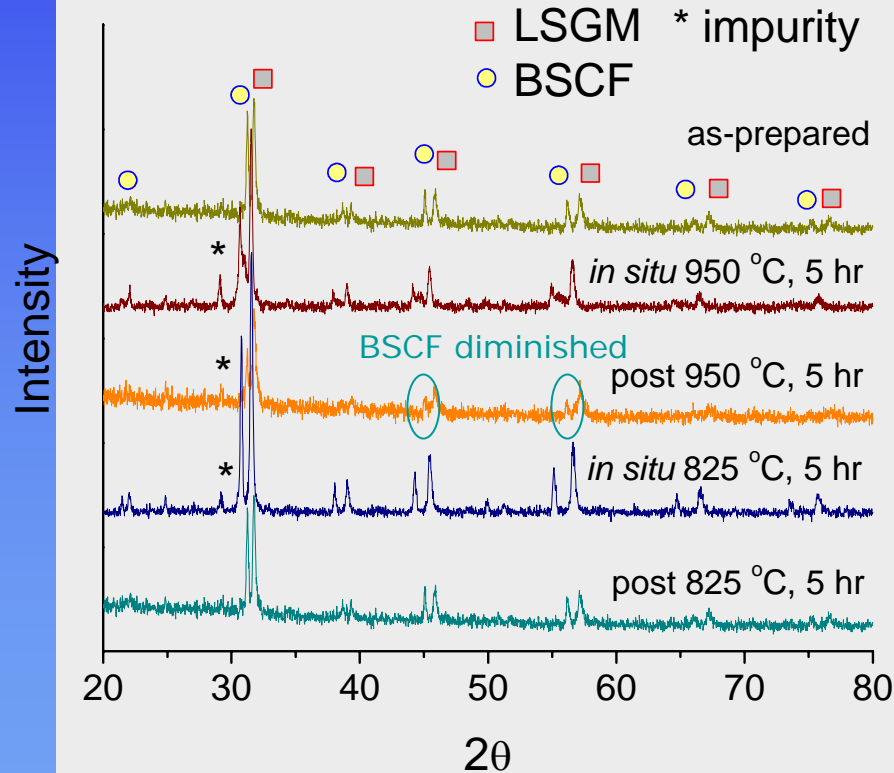
- **Comparison of EIS measured at 5 and 30 days**
 - Zero dc current
- **Total arc size actually decreases slightly over time**
- **Reason for change in shape is not known**



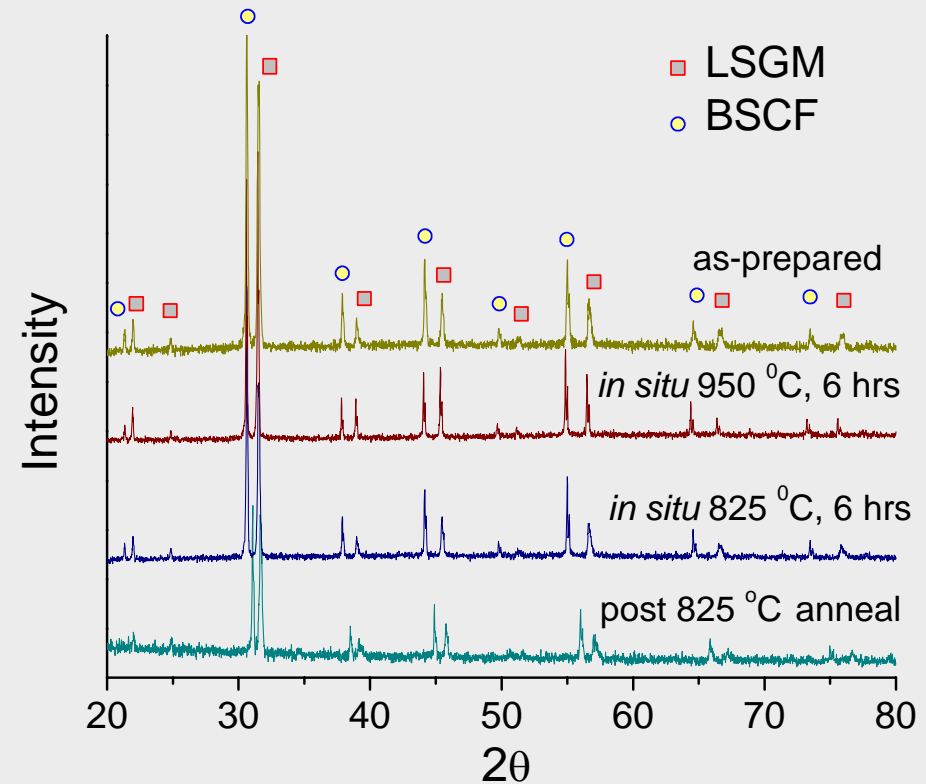
BSCF + LSGM Reactivity

- In situ* and *post situ* X-ray diffraction of LSGM + BSCF

Ceramatec LSGM



Northwestern University

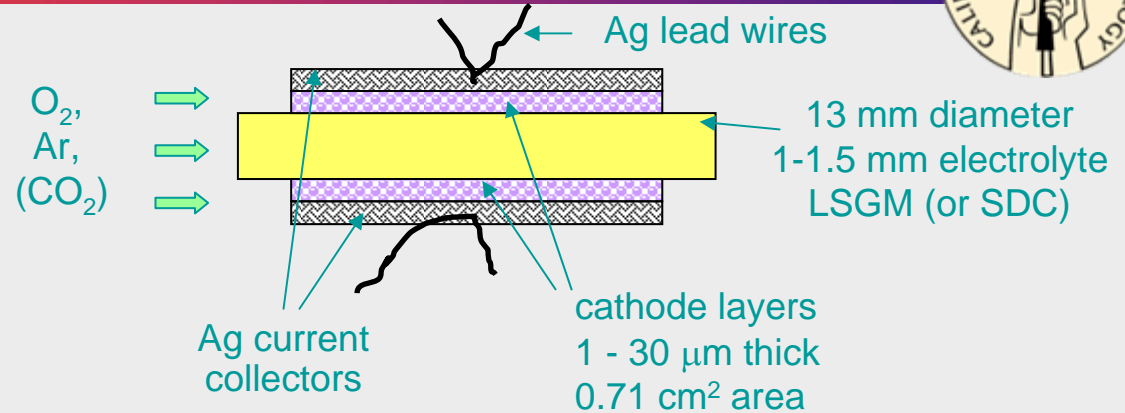


- Possible reaction with Ceramatec LSGM at high temperatures

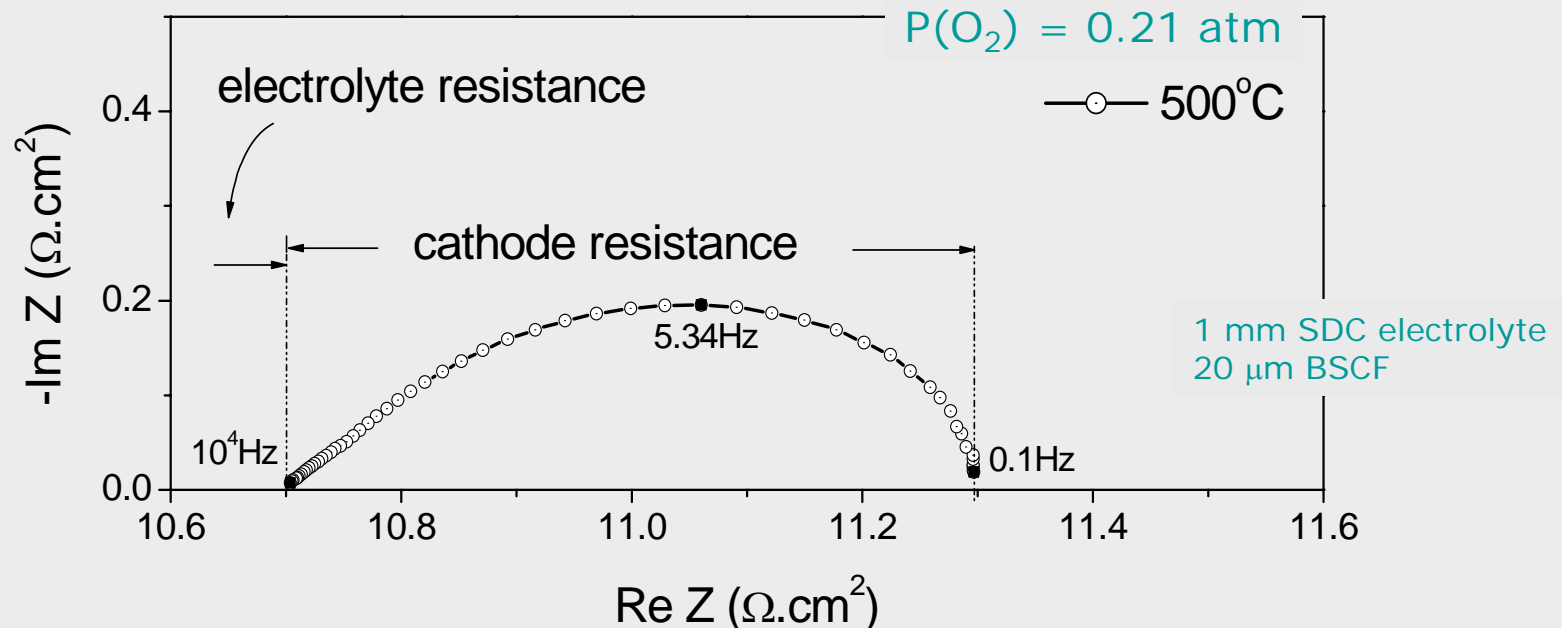
Oxygen Electroreduction



- Symmetric cell impedance measurements
- 2-electrode



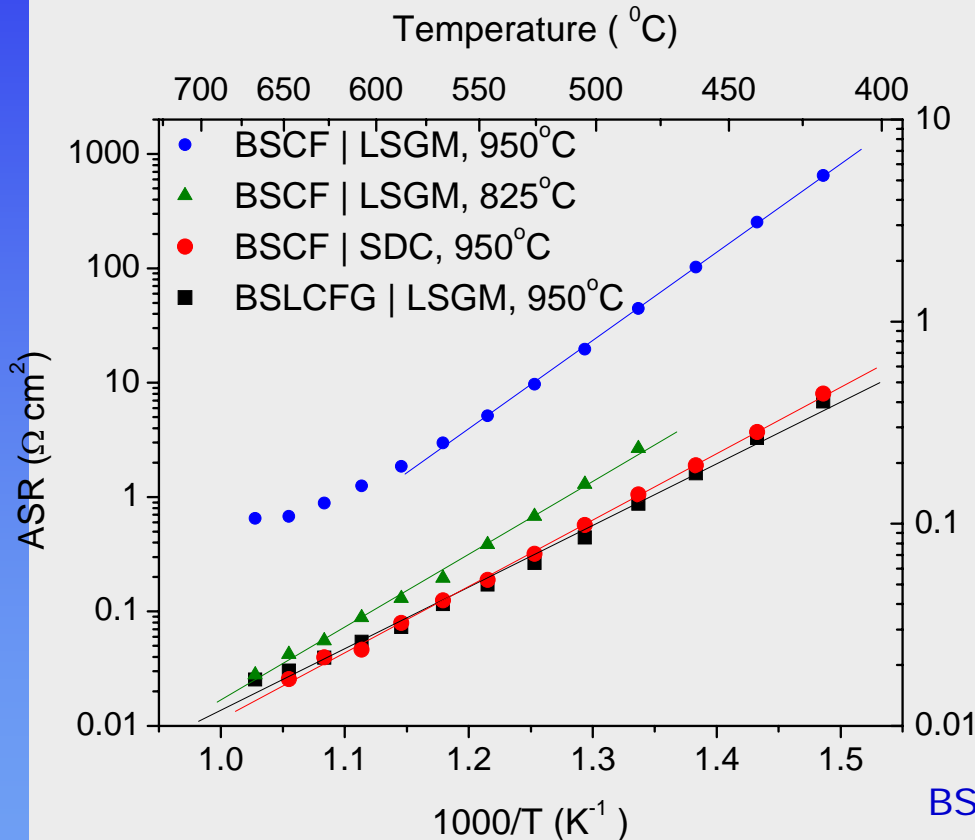
Typical impedance spectrum





Processing and Chemistry

- Symmetric cell impedance, 21% O₂ + Ar, identical thicknesses



System cath electr	R _p (600°C) $\Omega \text{ cm}^2$	E _g eV
BSCF LSGM 950C sinter	1.86	1.46(1)
BSCF LSGM 825C sinter	0.13	1.21(3)
BSCF SDC 950C sinter	0.079	1.02(2)
BSLCFG SDC 950C sinter	0.073	1.01(1)



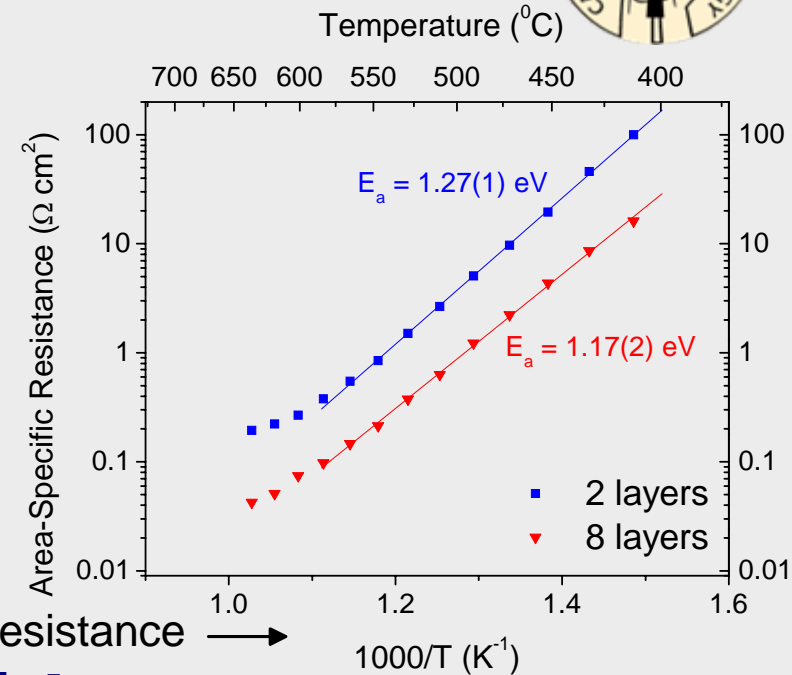
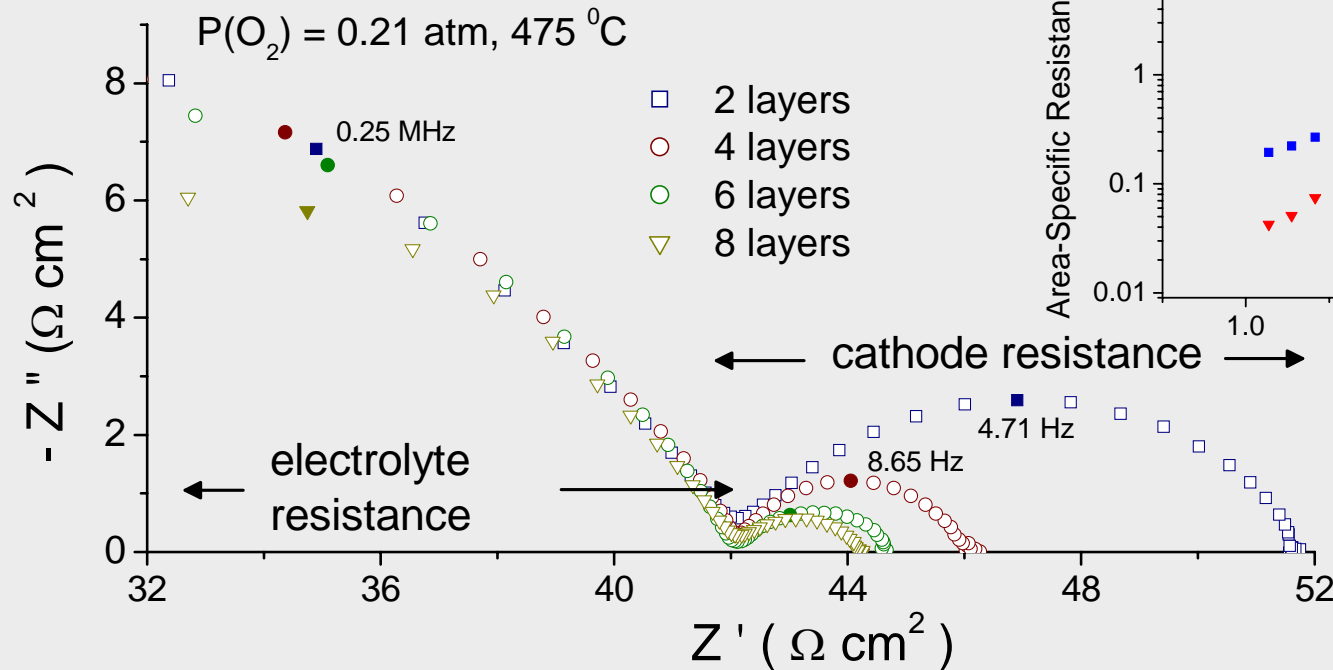
- Some detrimental reaction between (Ceramatec) LSGM and BSCF
- Nevertheless, extremely low polarization resistance



Oxygen Electroreduction

Influence of cathode thickness
(825 °C sinter)

~ 1.5-2 μm per layer



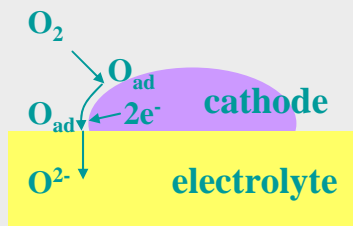
- Decreasing polarization resistance with thickness is atypical
- But, consistent with previous measurements on SDC, due to atypical mechanism



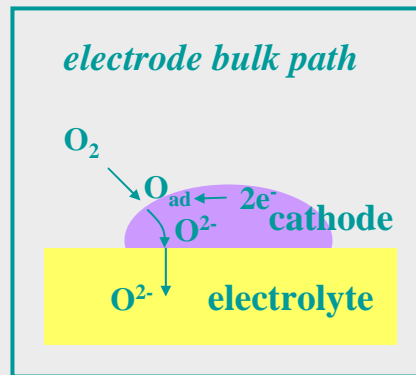
Electrocatalysis Mechanism

- Oxygen electro-reduction pathways

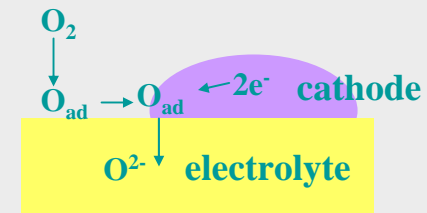
electrode surface path



electrode bulk path



electrolyte surface path



- $(Ba_{0.5}Sr_{0.5})(Co_{0.8}Fe_{0.2})O_{3-\delta}$
 - Exceptionally high oxygen vacancy diffusivity
 - Exceptionally high vacancy concentration ($\delta \sim 0.7$)
 - No indication of vacancy ordering/clustering
 - Surface related step is rate-limiting

Summary

- **Comparison of low temperature cathodes in progress**
- **LSCF and BSCF show low cathode contribution**
- **Button cells and stack tests planned to verify improved performance**