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ADVANCED MATERIALS & ELECTROCHEMICAL TECHNOLOGIES

Intermediate Temperature Solid Oxide Fuel Cell Development

SECA Core Technology Program Review Meeting

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Phase I DOE-SBIR Grant No. DE-FG 03-01ER83212

Period of Performance: Sept. 01 - Feb. 02

Outline

- Review of intermediate temperature electrolyte options
  - Opportunities and challenges
- Phase I electrode strategy
  - Phase I results
- Phase II plan

Current SOFC Electrolytes

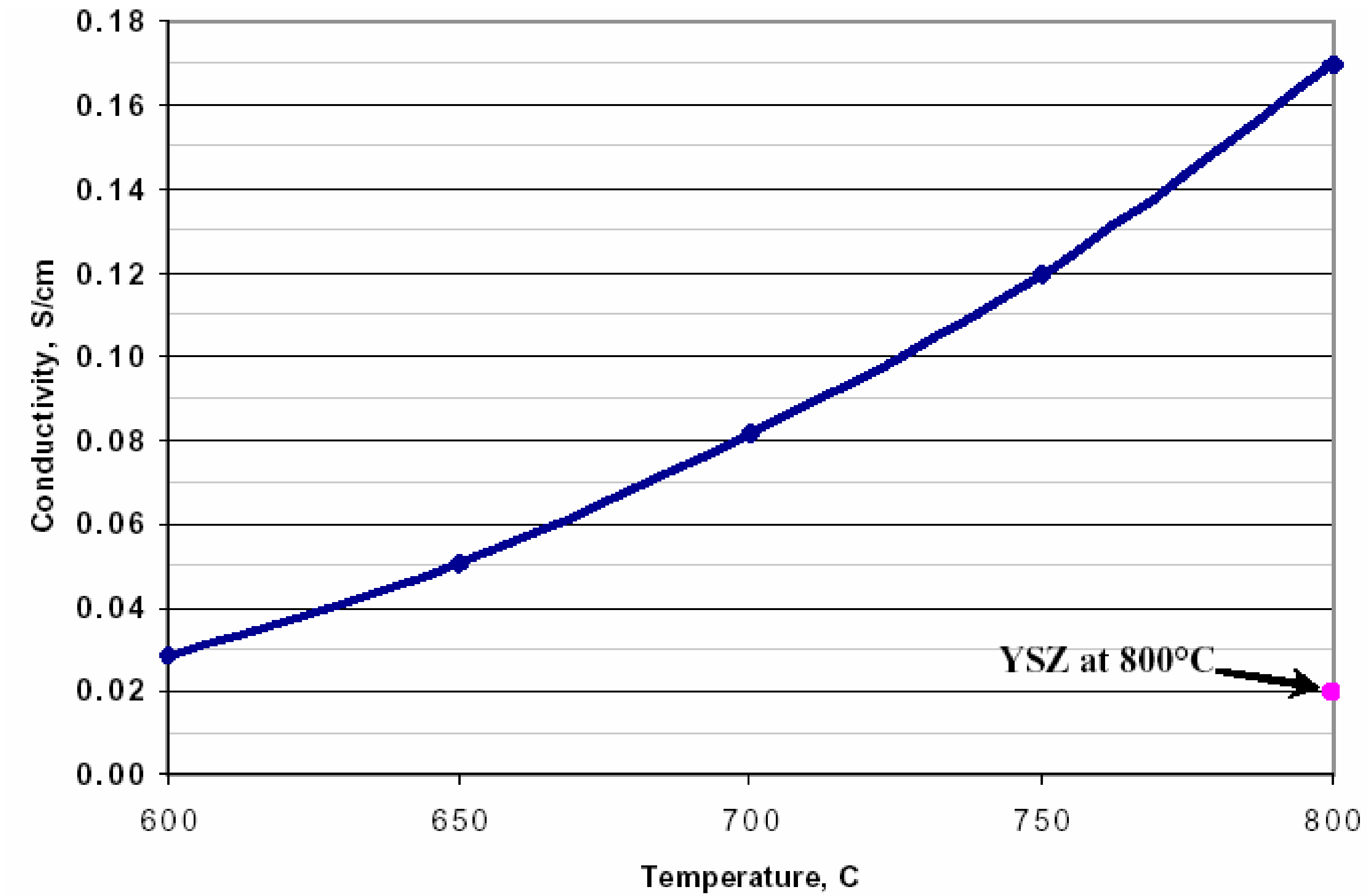
System	Electrolyte Issues	Anode Material and Issues	Cathode Material and Issues	General Comments
Zirconia	Low conductivity 0.1 S/cm at 1000°C 0.02 S/cm at 800°C	Ni-zirconia Ni coarsening	La(Sr)MnO_3 zirconate formation at the interface	Demonstrated No electronic leak current 1000°C Operation typical; very thin electrolyte allows 800°C operation; lower than 800°C not practical yet
Ceria	High conductivity (0.1 S/cm at 800°C)	Ni-ceria	La(Sr)CoO_3 CTE mismatch	Electronic short Differential expansion from air to fuel side
La gallate	High conductivity (0.1 S/cm at 800°C)	Ni-ceria Formation of La-Ni-O insulating phases	La(Sr)CoO_3 CTE mismatch	No electronic leak current CTE similar to zirconia Long term cell stability is an issue material cost

Lanthanum Gallate

$La(Sr)Ga(Mg)O_3$ (LSGM)

- High oxygen ion conductivity
  - Higher conductivity at 800°C than zirconia at 1000°C
- Stable in fuel
  - Ionic transference number ~1 over the entire pO_2 range of interest
- Challenges
  - Anode reactivity
  - Strength

LSGM Conductivity



- Ionic conductivity at 750°C ~ zirconia at 1000°C

Phase I Strategy for Electrodes

Anode

Present Anode: Ni-Ceria or Ni-LSGM

- Objective:
  - Eliminate or reduce reaction between La (in electrolyte) and Ni (in anode)
- Approach:
  - Additive to the anode that will reduce the reaction
  - Verify using powder reactivity studies

Phase I Strategy for Electrodes

Cathode

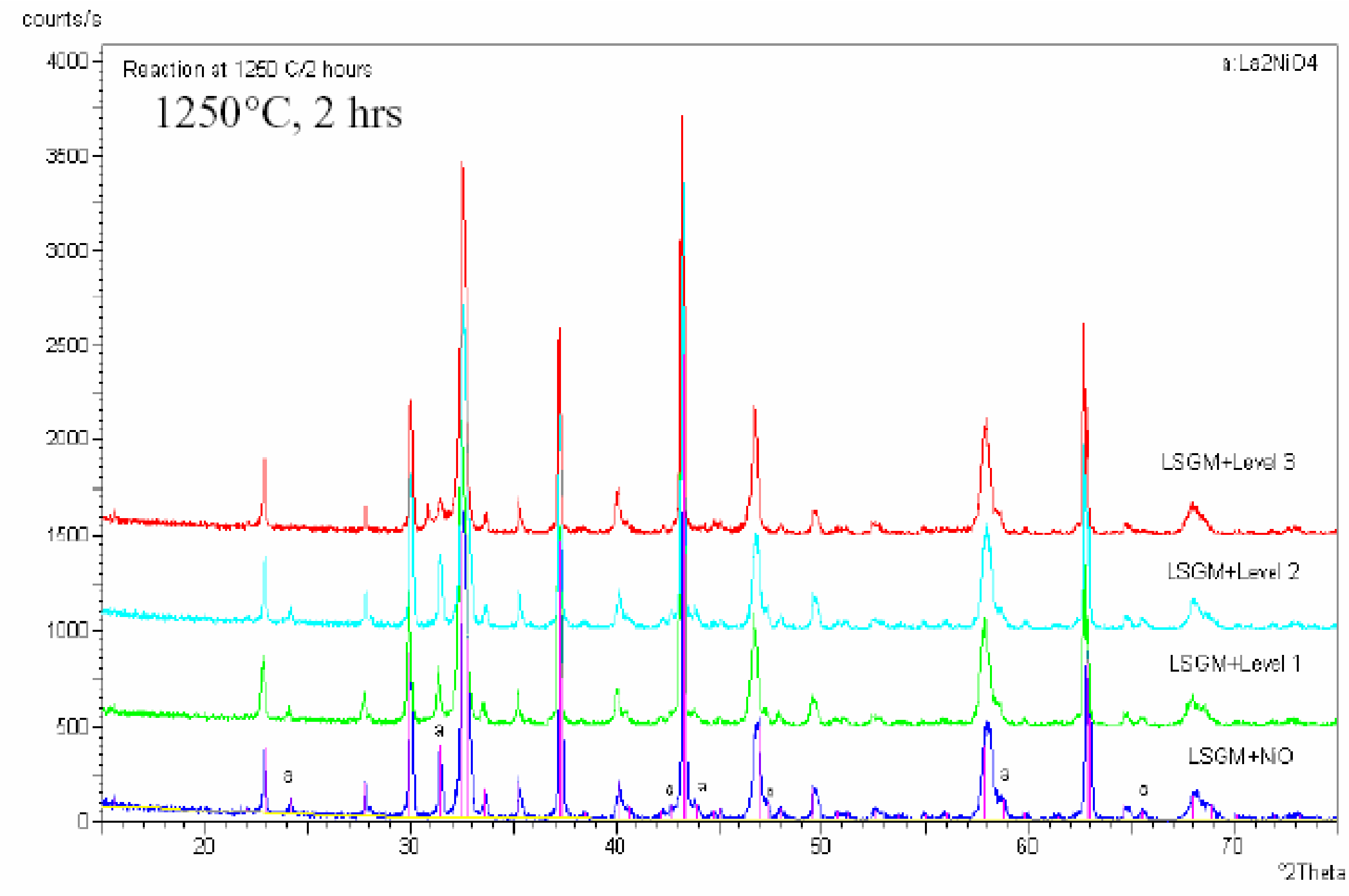
Present Cathode: $La(Sr)CoO_3$

- Objective:
  - Lower cathode thermal expansion coefficient
- Approach
  - Doping in B-site (replacing Co) may lower CTE

Reactivity Studies

- Common reaction products
  - $LaNiO_3$, La_2NiO_4
- Powder mixtures of modified Anode and LSGM
  - 1250°C, 2 hours and 6 hours
  - 1350°C, 6 hours
- 1250°C - potential electrode firing temperature for sintered electrolyte
- 1350°C - potential sintering temperature for an anode supported bi-layer

XRD - Reaction Study



- Additive Level 3 - significant reduction in second phase content at 1250º C

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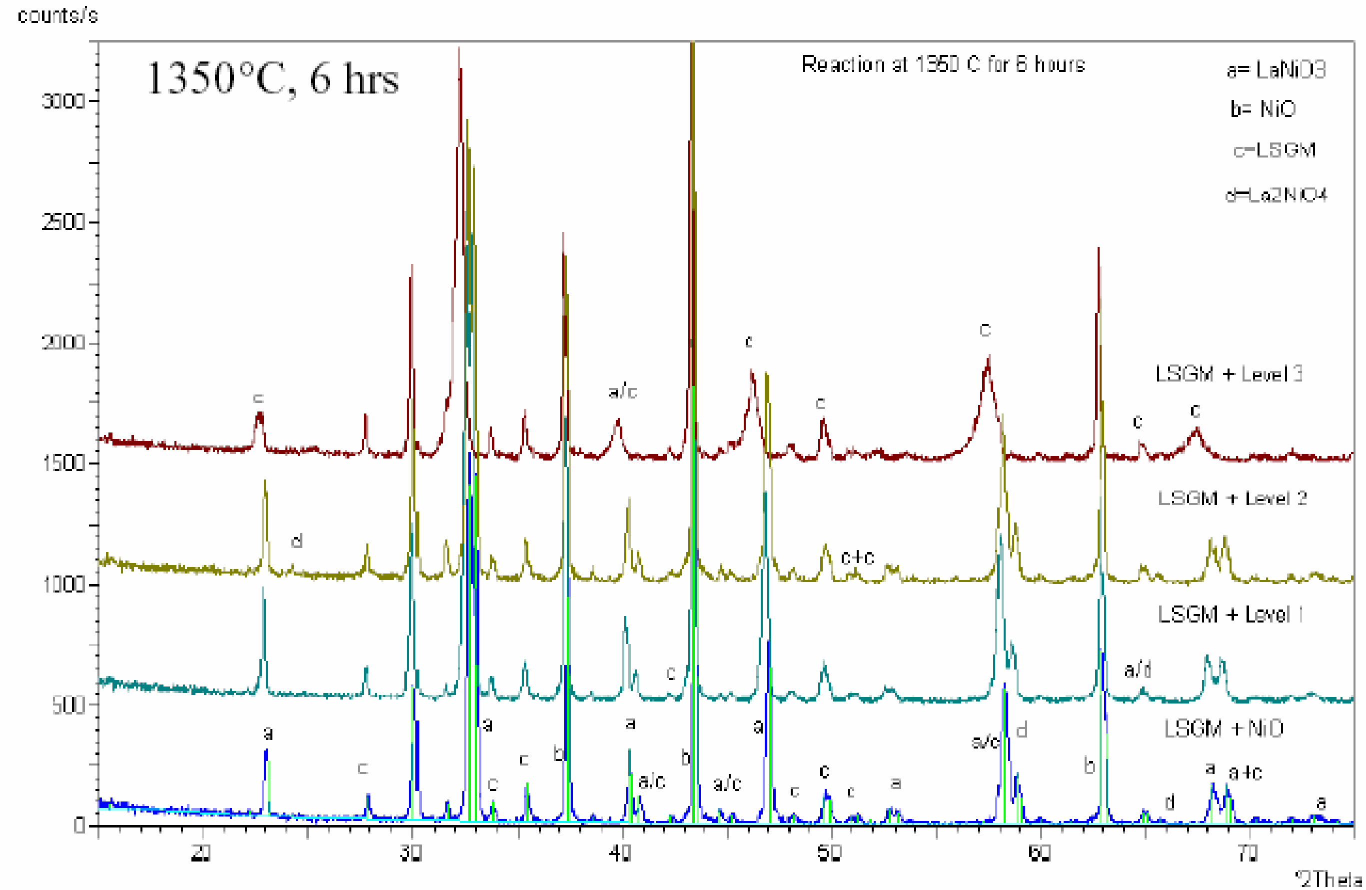
XRD - Reaction Study



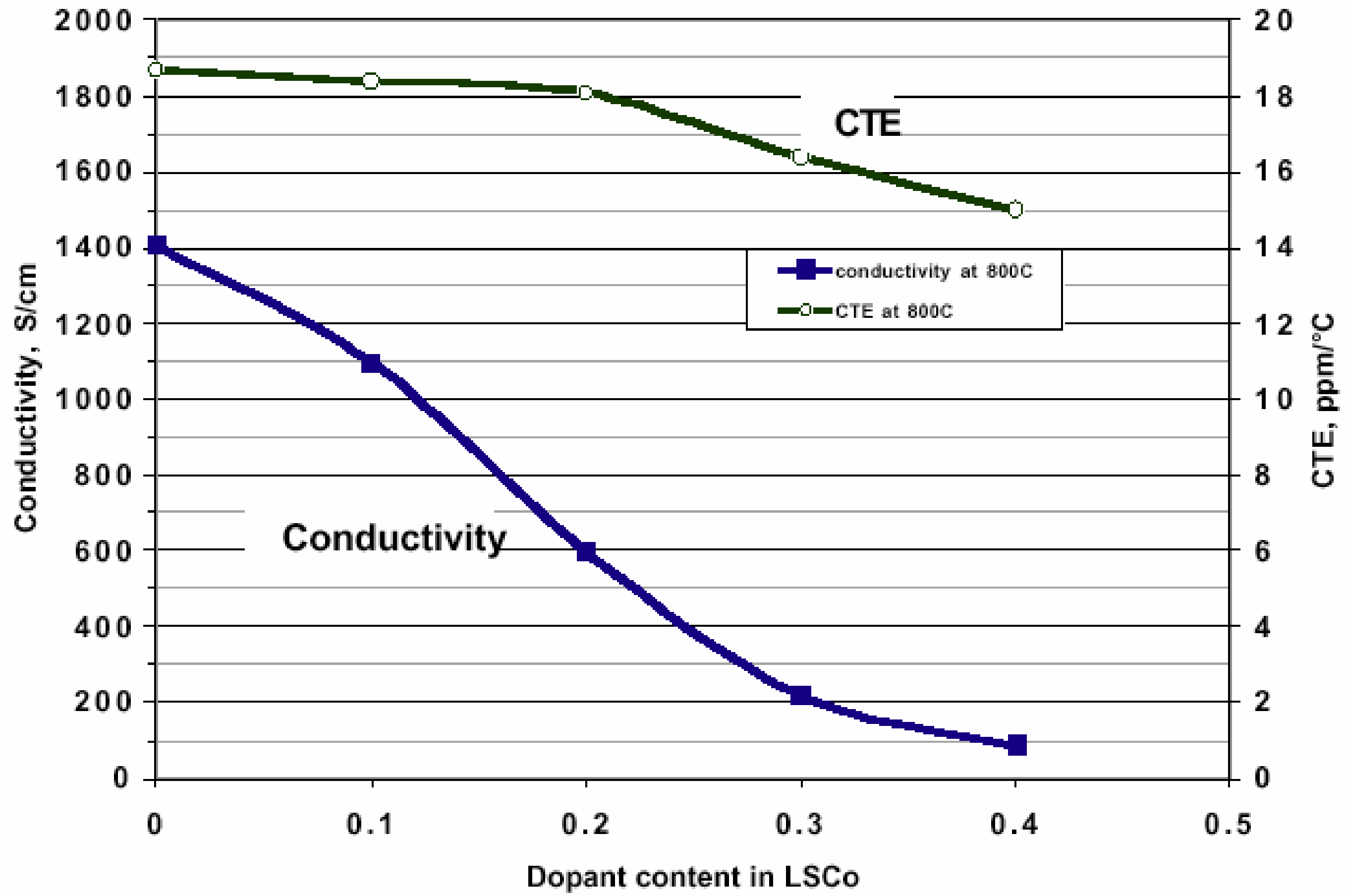
- Additive Level 3 - significant reduction in second phase content even at 1350º C

Conclusion of Anode Study

- Reaction with LSGM
  - Reaction products: 1250°C La_2NiO_4
    1350°C $LaNiO_3$
  - Reaction products below detection limit even at 1350°C, 6 hrs in powder mixture
- The modified anode will allow anode supported thin gallate electrolyte

LSCo Cathode Evaluation

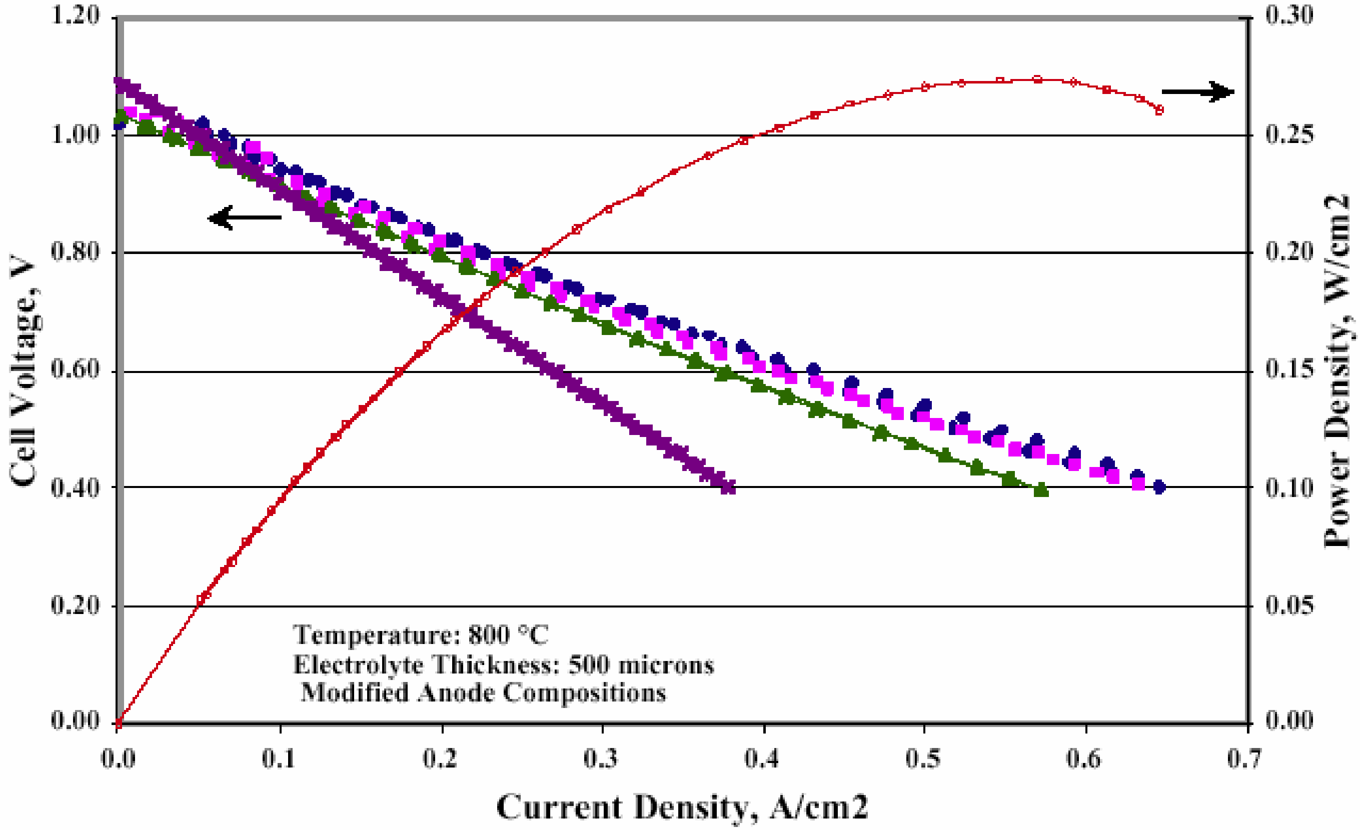
CTE and Conductivity



Conclusion of Cathode Evaluation

- B-site doping only slightly decreases the CTE
- Decrease in conductivity is rapid with B-site doping
  - The conductivity of doped LSCo is still high even at 600°C: 600 S/cm
  - CTE is still high at 18 ppm/°C
  - Cathode is likely fired at a lower temperature
    - Effect of mismatch would be lower
- No new phase formation detected at 1350°C, 6 hrs

Single Cell Performance



- > 1 V OCV indicating good ionic transference number
- ASR 1 ohm.cm^2 with newer electrodes and 500 micron electrolyte

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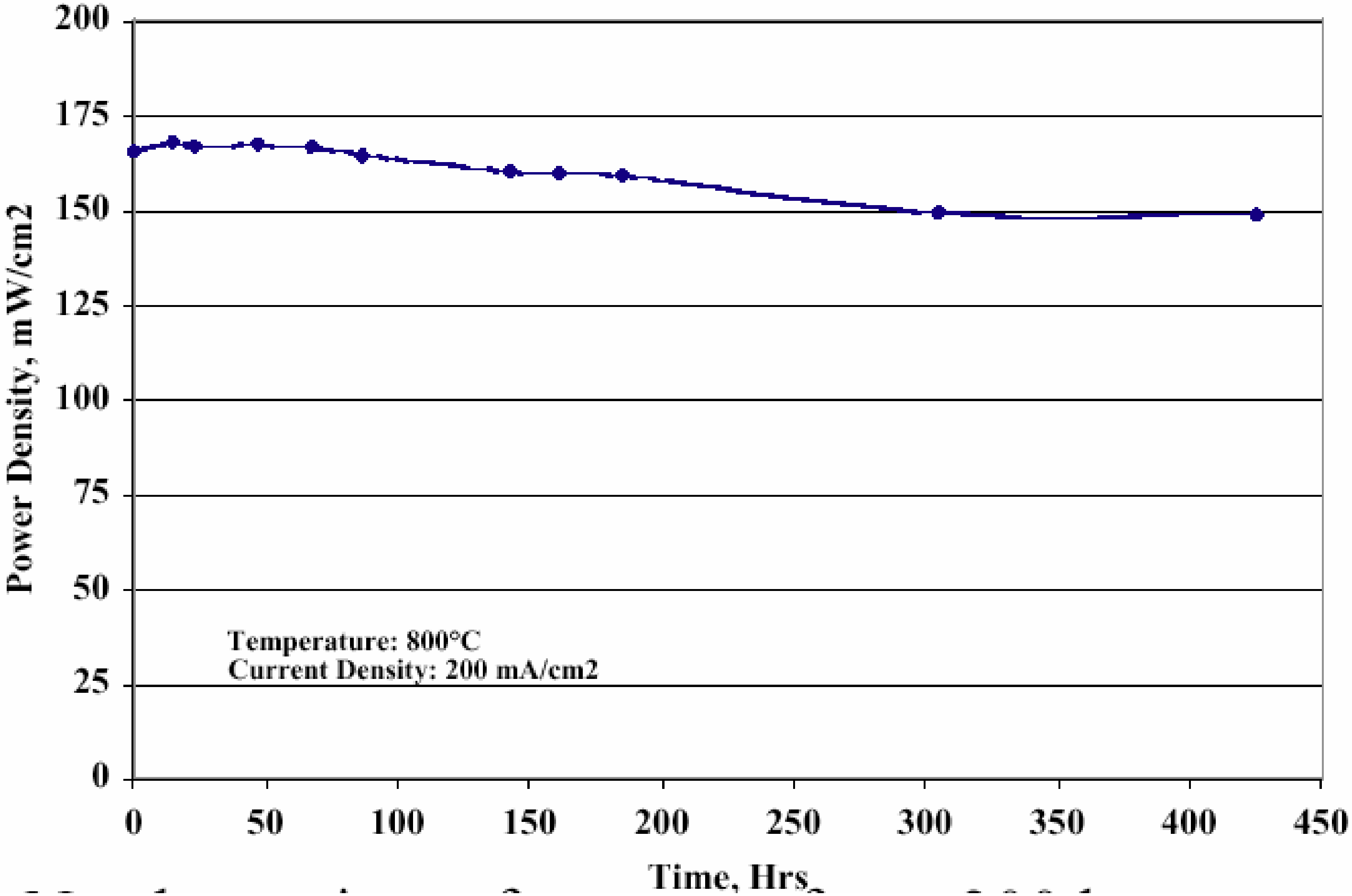
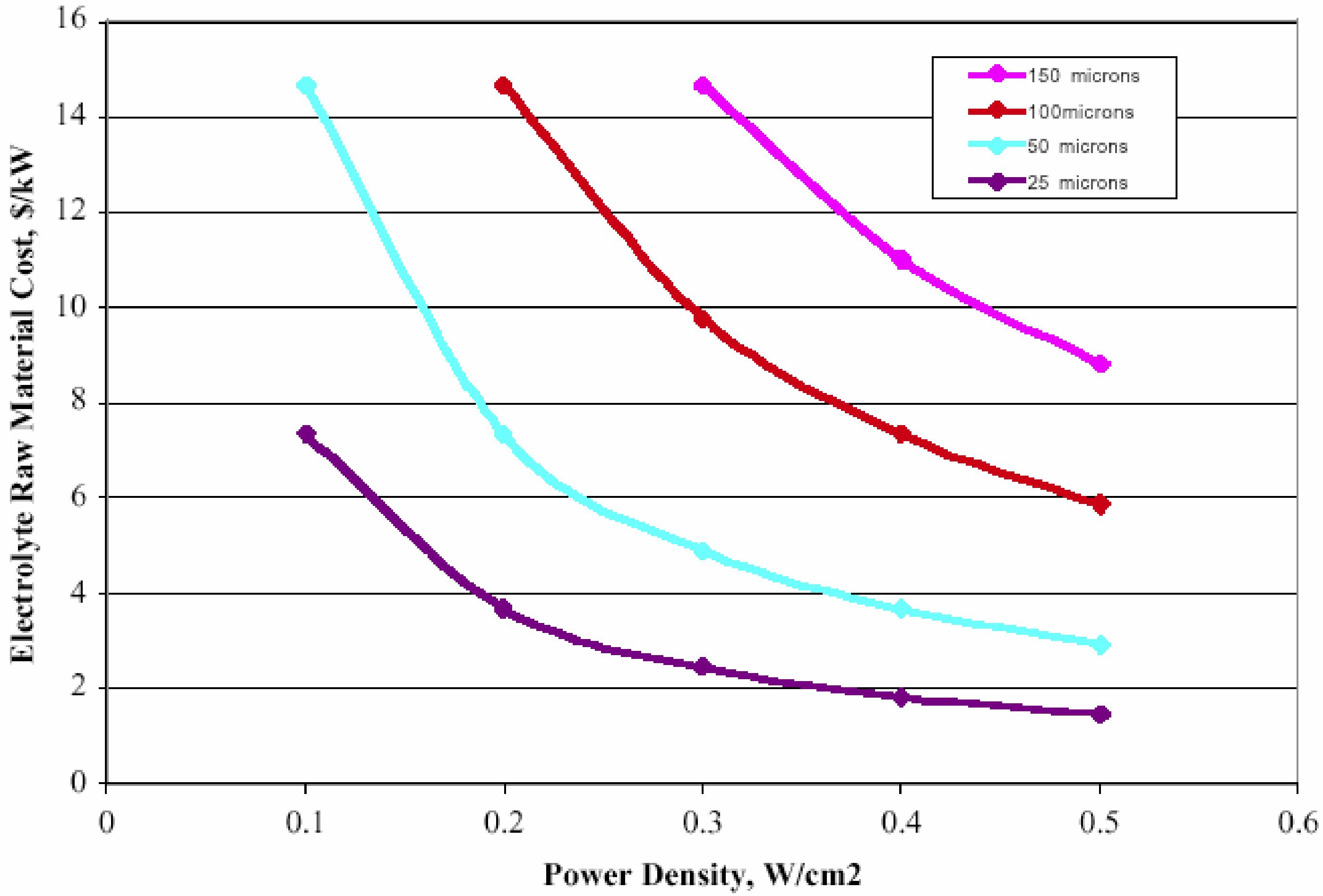
Initial test on performance stability



- No change in performance after ~ 300 hours

LSGM Raw Material Cost Estimate



Summary of Phase I

- LSGM is a promising electrolyte for low temperature operation
- Reactivity with anode was addressed in Phase I
  - Anode composition with the promise of bi-layer compatibility developed
- No reaction product with LSCo cathode
  - Cathode less likely to be an issue

Technical Directions

- Cell Fabrication
  - Electrolyte thickness
  - Electrode microstructure
  - Fabrication conditions
- Electrolyte Strength
  - Literature Strength Data: 160 MPa at room temp. and 55 MPa at 900°C
  - Approach: Anode supported

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Phase II Plan

- Technical Issues
  - Electrolyte sintering temperature
  - Strength of electrolyte
  - Bi-layer fabrication development

- Phase II Team
  - Ceramatec - Materials, Fabrication, Testing
  - Sandia National Labs. - Electrolyte Strength
  - New Mexico Tech. - Ceramic Process Development