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CERCANAM® Insulation for Solid Oxide Fuel Cells

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Requirements for SOFC Insulation

- High temperature thermochemical stability in air and fuel atmosphere (physical, chemical, microstructural)
- Very high heat transfer resistance
  - Low thermal conductivity
  - Low convective heat transfer through pores
  - Minimization of heat transfer through radiation
- Ability to fabricate in near-net shape
- Low cost

Limitations of Commercial Insulation for SOFC Applications

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- **Low cost insulation materials:**
  - Contain silica
  - Evolve SiO on exposure to H_2O at high temperatures
  - SiO degrades the electrodes and puts limitations on long-term SOFC performance.
- **Conventional high-alumina (low-silica) insulation:**
  - Requires very high-T sintering
  - Very high fabrication and machining costs

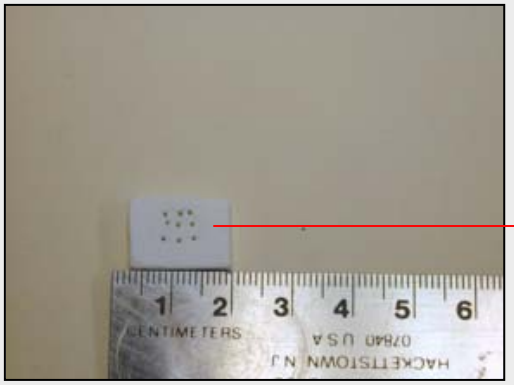
CERCANAM® Materials

- CERCANAM:® CERamatec CAstable NAno-Materials
  - Feasibility of microfabrication with very high dimensional tolerance.
  - Near net-shape processing with minimal post-machining.
  - Technologically simple, one-step processing even for complex geometries that would require multiple-step processing with other technologies/materials.
  - Significantly lower processing costs and production times for complex geometries.
  - Scalability to large volume production with very high component production rates.

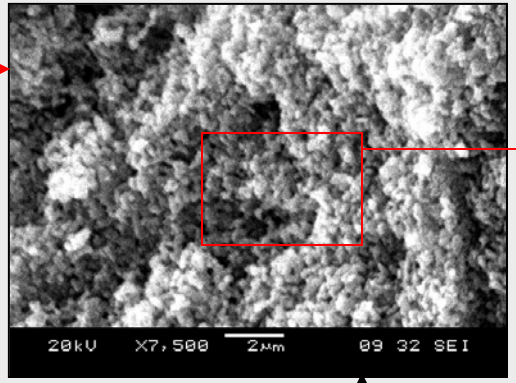
Benefits of CERCANAM® for SOFCs

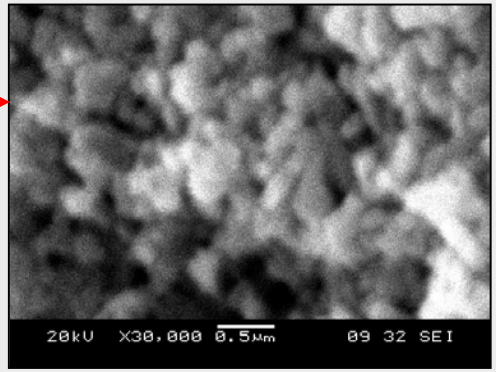
- Ultra-low silica composition
- Low cost
- Excellent thermal cycling/thermal shock properties up to at least 1000°C.
- Thermochemical stability at least up to 1000°C.
- Microporous/nanoporous structure gives excellent heat transfer resistance without compromising thermal shock properties.
- Flexural strength can be as high as 60-70 MPa (Lower at higher porosity).

Microstructure of CERCANAM® Materials



Bulk CERCANAM® specimen





Net-worked sub-micron and nano-porosity in cast CERCANAM® which can result in over 100 m^2/g component surface area

Thermomechanical Properties of CERCANAM®

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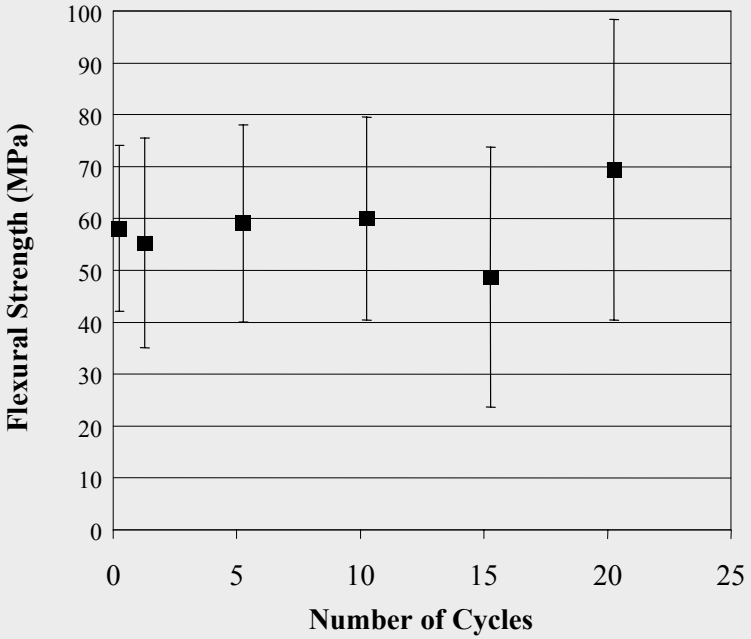
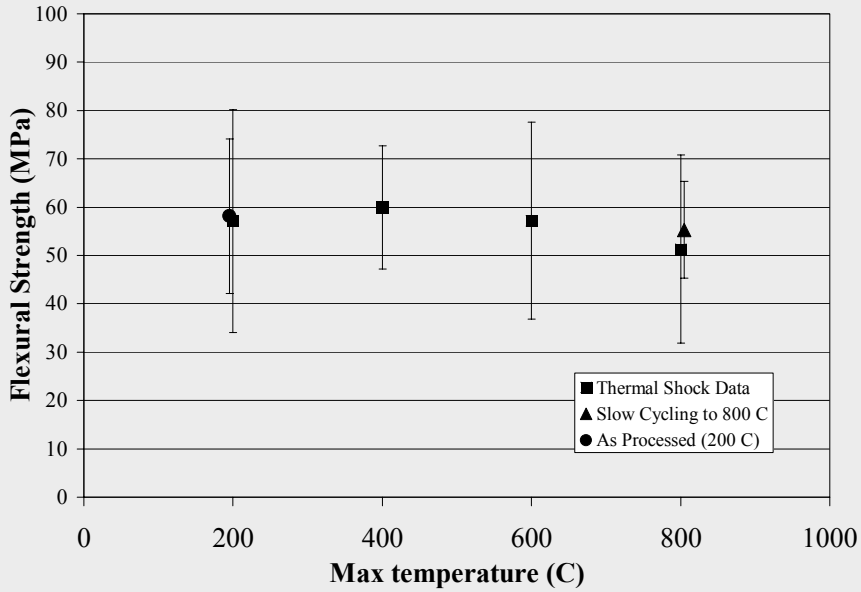
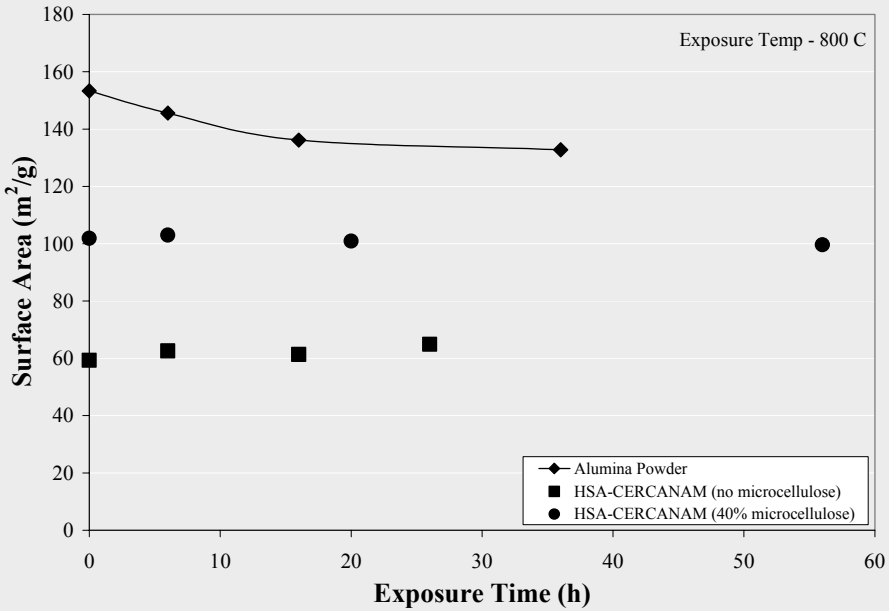
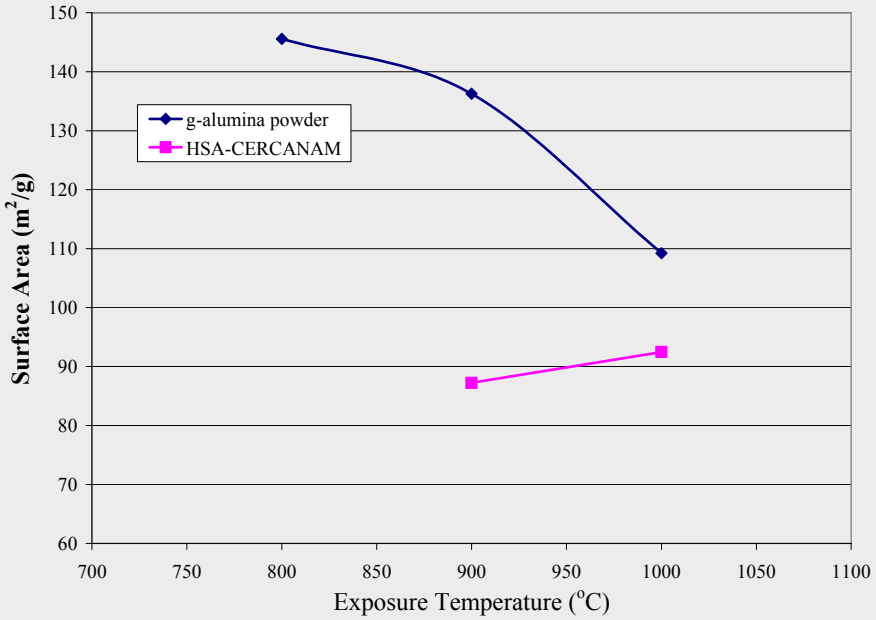


Thermal Cycles:
2 C/min to 800 C
1 h hold at 800 C
4 h slow cool in furnace



CERCANAM® Thermal Stability





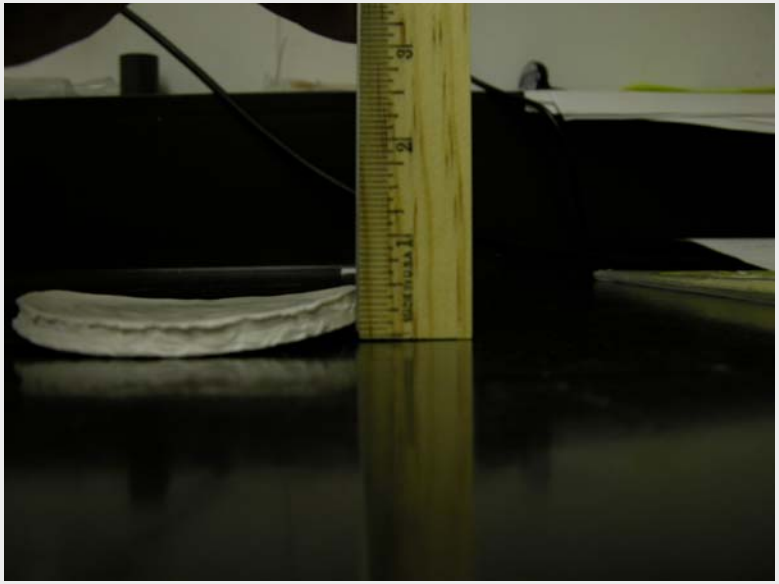
CERCANAM® retains its surface area up to 1000°C, while γ-Al_2O_3 does not.

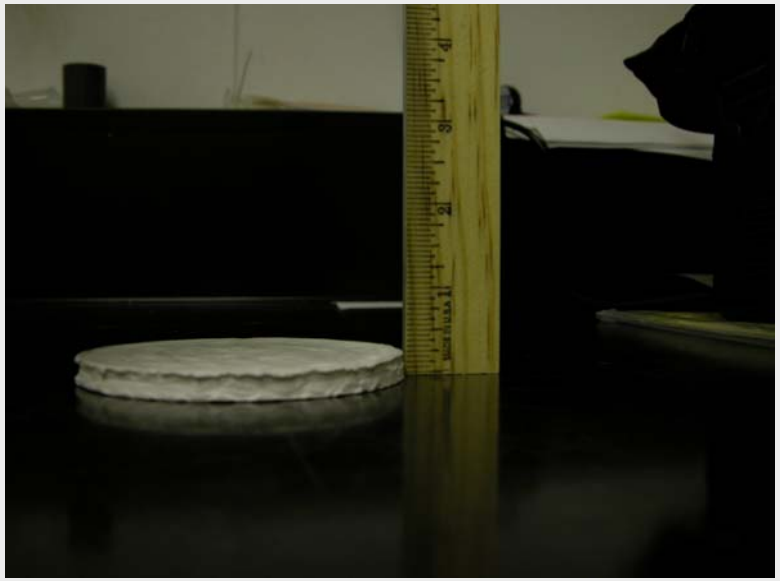
Phase I Program Goals

- Fabricate 6” × 6” × 1/4-1/2” CERCANAM plates with minimal post-machining
- Demonstrate the thermal shock resistance and thermal cycling resistance of 6” × 6” × 1/4-1/2” CERCANAM plates at temperatures up to 850°C.
- Demonstrate the intermediate term (500 h) thermochemical stability of CERCANAM materials in high-temperature air, hydrogen and reformate environments.
- Demonstrate the stability of short-term (100 h) stability of SOFC anodes and anode/electrolyte interfaces in fuel passed over CERCANAM at 850°C.
- Evaluate heat transfer resistance of CERCANAM materials and laminates/graded structures through a modified gaurded hot-plate technique technique.
- Generate raw-material cost vs material property databases.

CERCANAM® Warpage Minimization

- CERCANAM warpage can be minimized by pressing green bodies with plasticizer added.
- Upon firing, CERCANAM materials retain their green dimensions and shape.

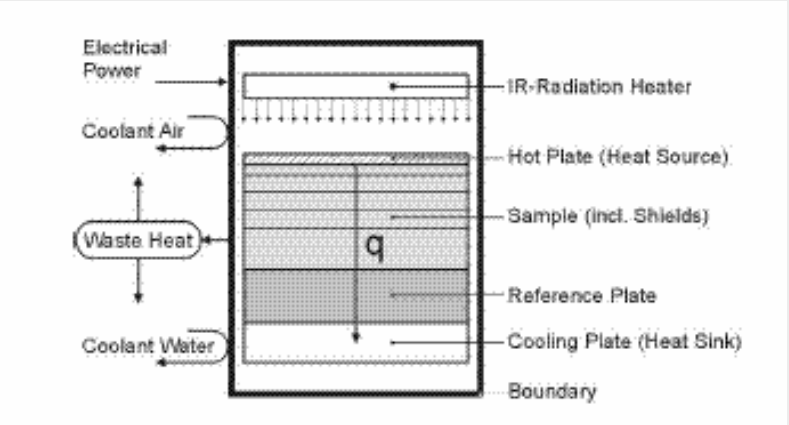




Heat Transfer Resistance Measurements

- Heat transfer resistance measurements will be made using a modified guarded hot-plate apparatus
- Design modifications will be made such that conduction, convection and radiation components can be taken into considerations

Gaurded Hot-Plate Apparatus Schematic



Cited from: "Experimental and Theoretical Studies on High-Temperature Multilayer Insulation," M. Spinnler, E.R.F. Winter and R. Vishkanta, 26th International Thermal Conductivity Conference Proceedings.

SOFC Performance with CERCANAM® in Fuel Stream

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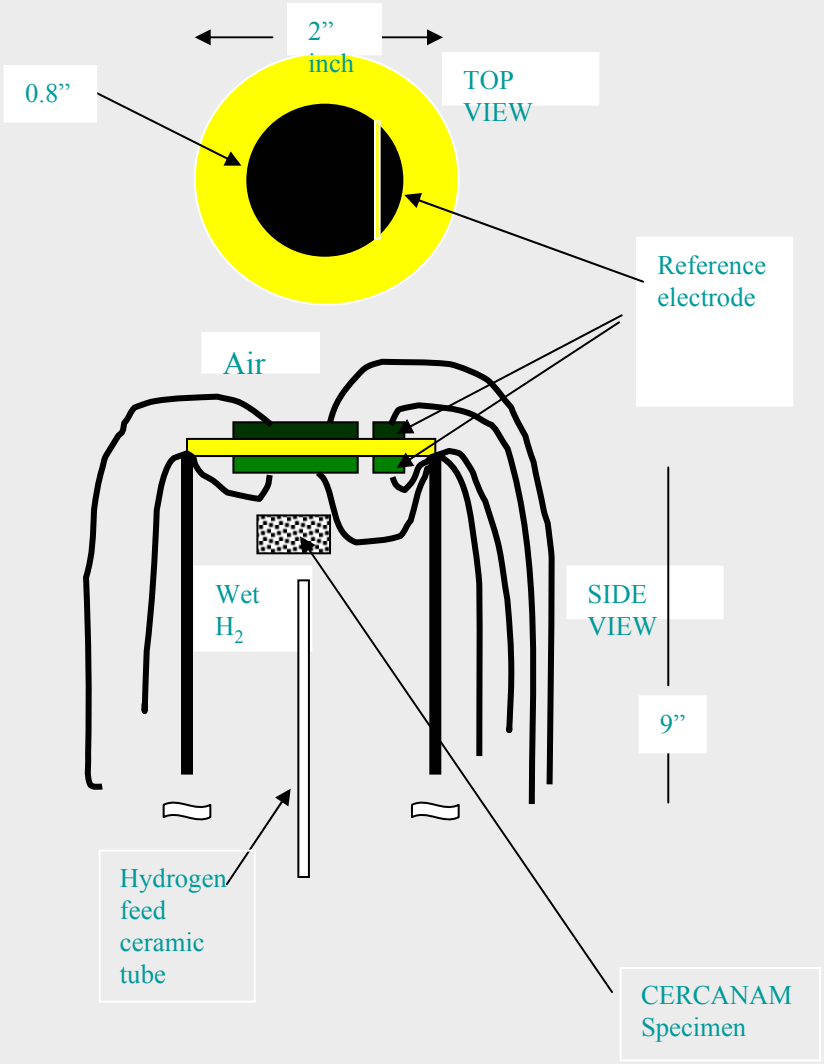

- Experiment designed to study if the presence of CERCANAM on the hot fuel side of an SOFC has any adverse effects on long-term steady-state cell performance.
- Over 120 hours of testing done (test still in progress).

Performance of SOFC with CERCANAM® piece in the fuel stream

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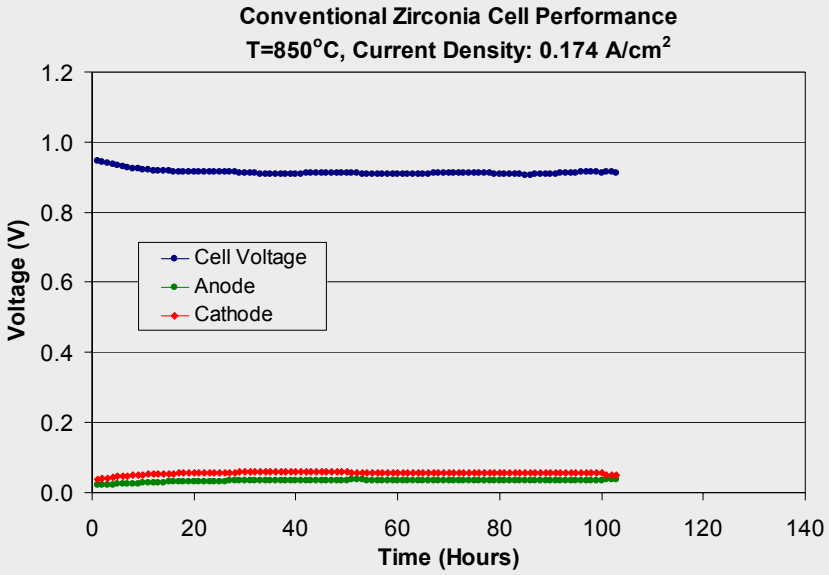
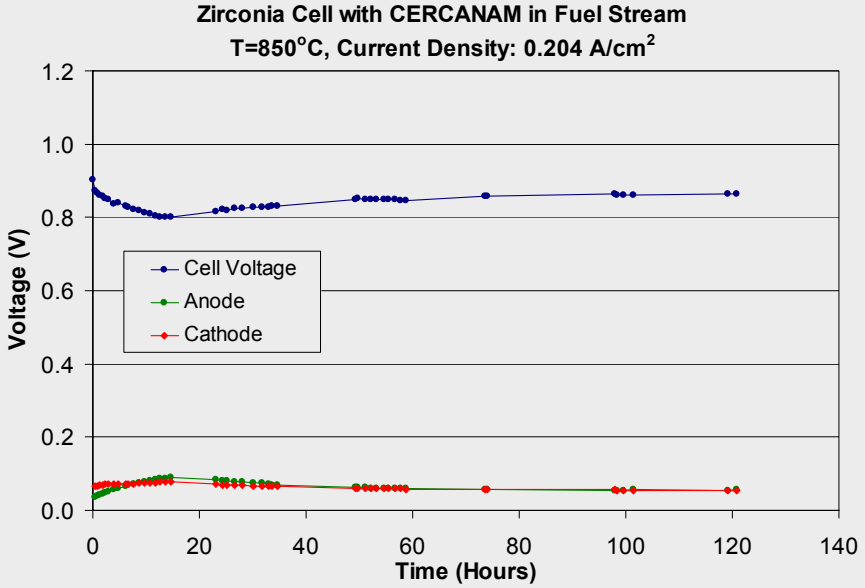
Cell Voltage Vs Time





- Steady state cell voltages are different due to different current densities
- The voltages of the cell with CERCANAM subsequently stabilized and approached steady state with no obvious long-term degradation
- Initial drop in cell voltage probably related to moisture evolution from CERCANAM

Performance of SOFC with CERCANAM® piece in the fuel stream

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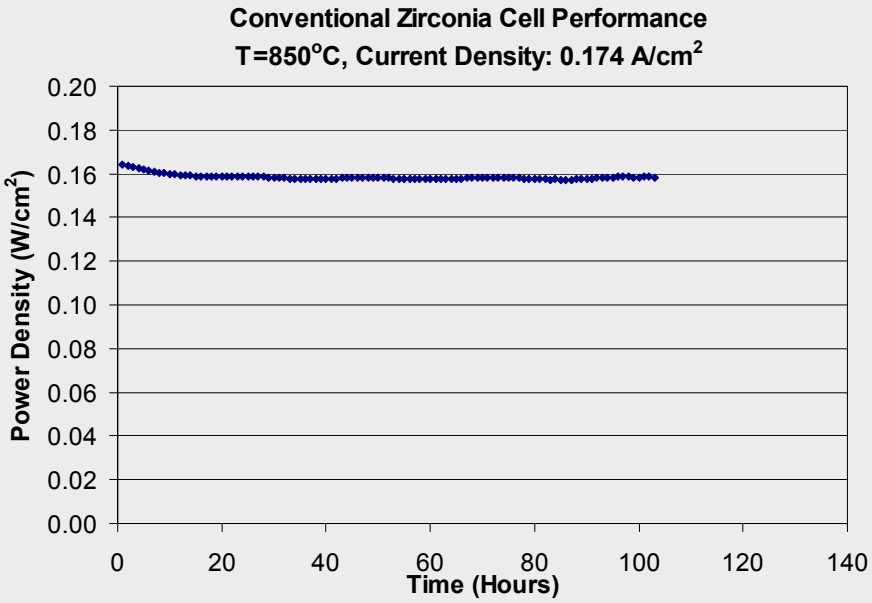
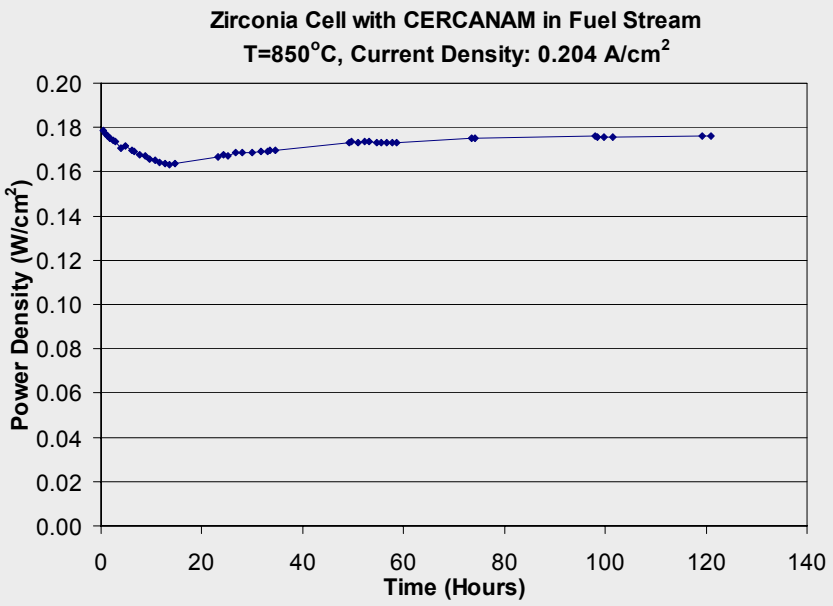
Power Density vs Time





- The initial trend in cell voltage due to moisture evolution is also reflected as an initial decrease in power density
- The power density of the cell with CERCANAM subsequently increased and approached steady state with no obvious long-term degradation

Ongoing and Future Work

- SOFC performance studies with and without CERCANAM® in the fuel stream in similar cells at the same current density
- Thermochemical stability experiments of CERCANAM® in air and fuel
- Experiments to determine heat transfer resistance of CERCANAM® with and without metallic shielding layers.
- Materials cost vs materials performance databases

Timeframes for Technology Development and Commercialization

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- **6/2003-5/2004** - Phase I: Feasibility Demonstration
- **7/2004-7/2006** – Phase II: Process optimization, prototype development
- **2005-2007** – Phase III: manufacturing process development, scale up
- **From 2007 Onwards**: Commercial sales of custom net-shape insulation to SOFC manufacturers

Technology Development and Commercialization Goal

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Ceramatec's goal is to **interact with SECA vertical teams** during the Phase I project, and **develop teaming arrangements for Phase II** (prototype development and integration into SOFC stacks at partner sites) and **Phase III** (Commercialization). After successful completion of the Phase I and Phase II projects, Ceramatec will be able to **offer a line of custom-sized net-shape CERCANAM® insulation components** to SOFC manufacturers, based on specifications supplied by them, ready for integration into commercial SOFC systems.

Acknowledgement

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