Advanced Net-Shape & Net-Size Insulation for Solid Oxide Fuel Cells

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Requirements for SOFC Insulation

- High temperature thermo-chemical 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

- 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, net-size 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.

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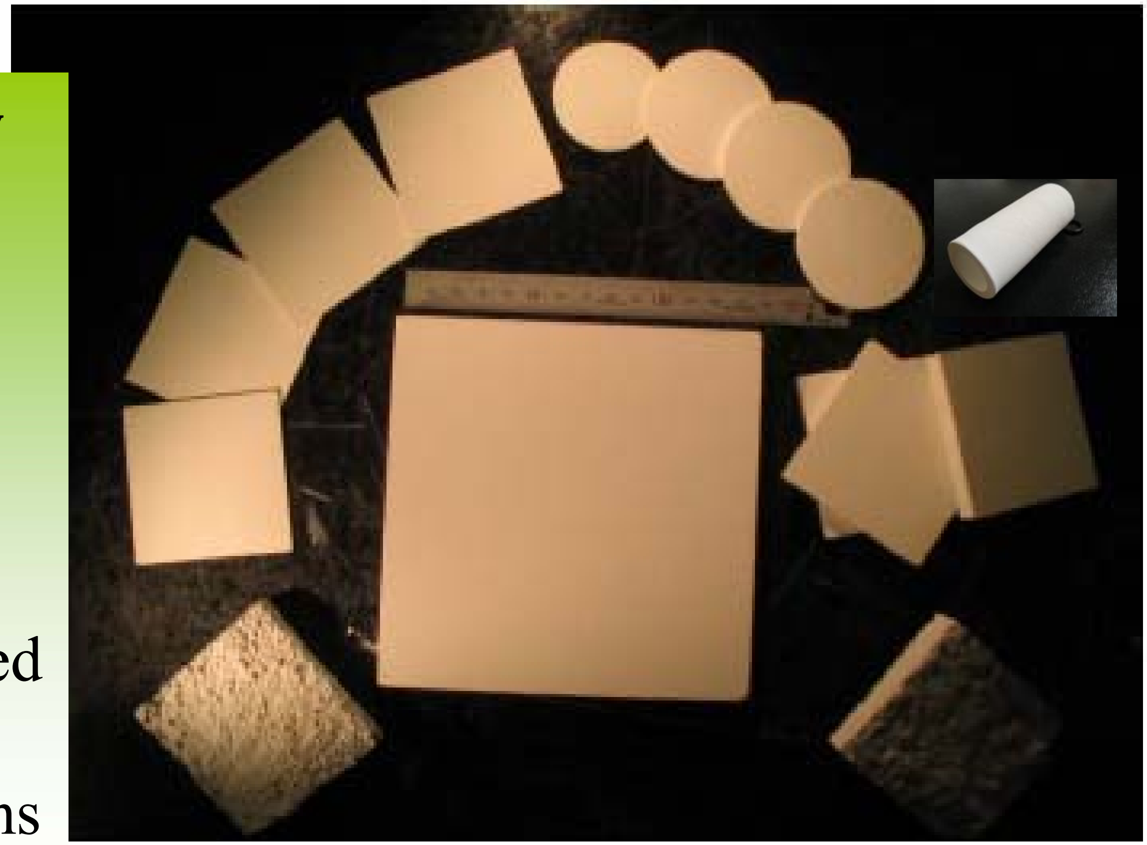
Benefits of CERCANAM® for SOFCs

- 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 50-70 MPa (Lower at higher porosity).

Advantages of a Net-Size and Net-Shape Process

Developed a proprietary processing route for CECANAM

- Reduced cost due to minimum post-machining
- Very simple process
- Easily scalable
- Density can be controlled by controlling processing conditions, & compositions



Green-to-fired shrinkage: ≤0.5%
Firing Temp: 800°C-1000°C

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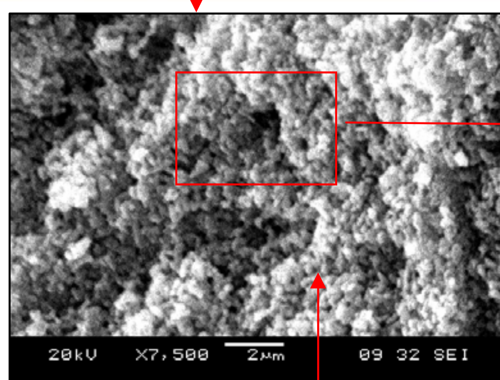
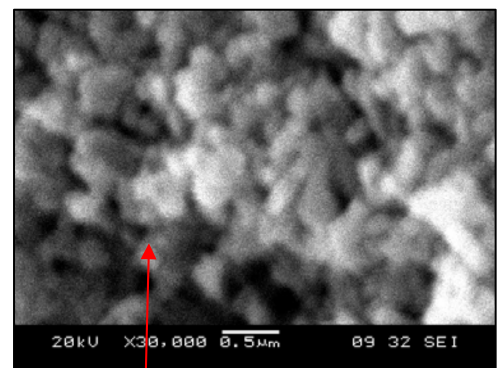
CERCANAM® Materials Microstructure

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

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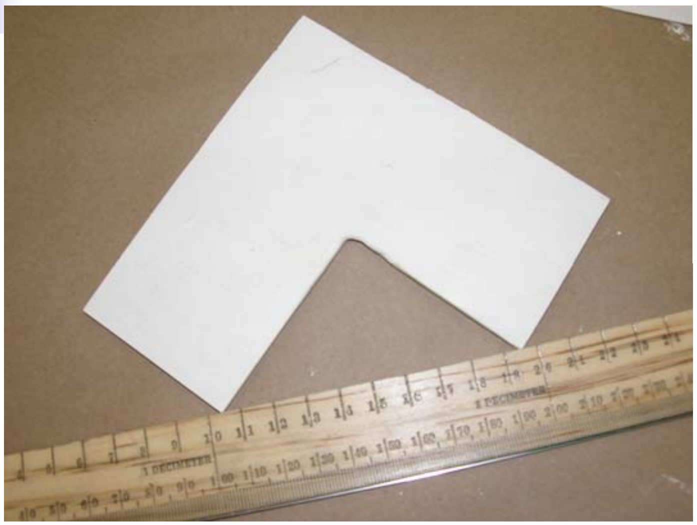
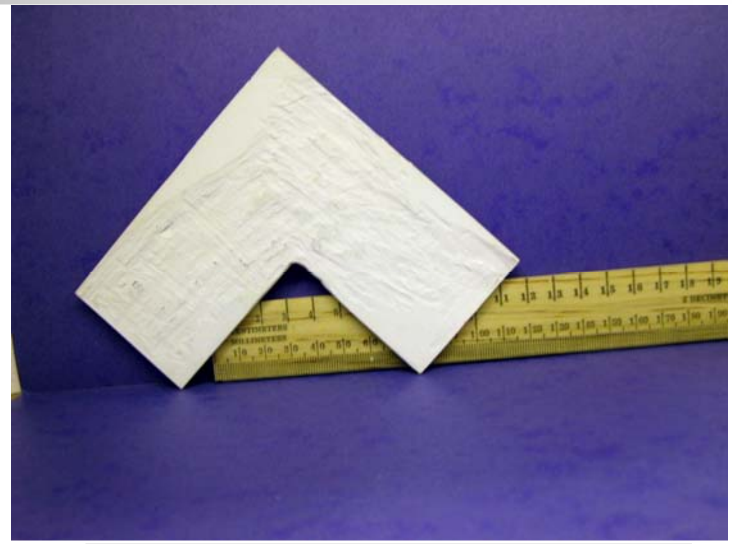
Thermal Cycling/Thermal Shock Resistance of CERCANAM®



Before Thermal Tests

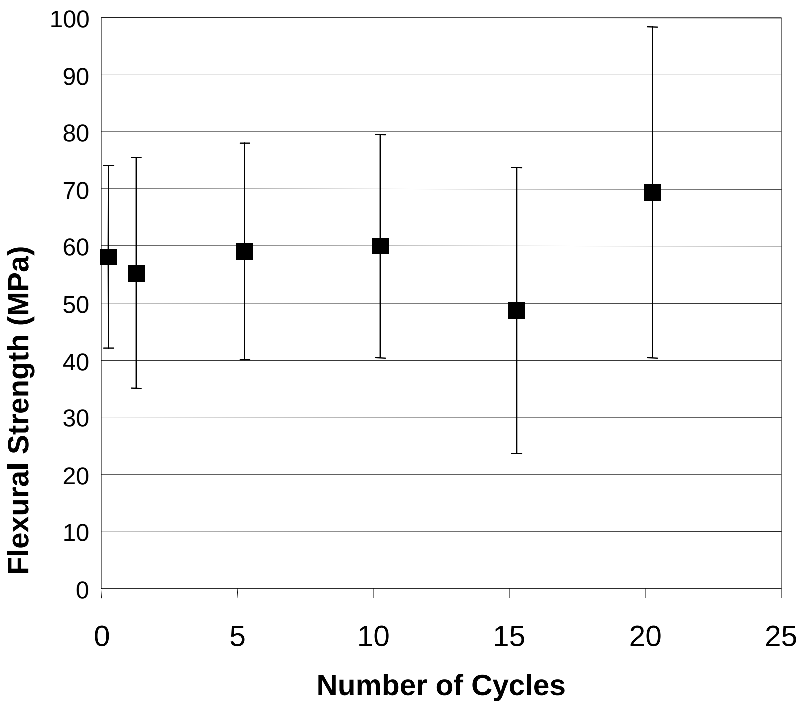


After Thermal Tests

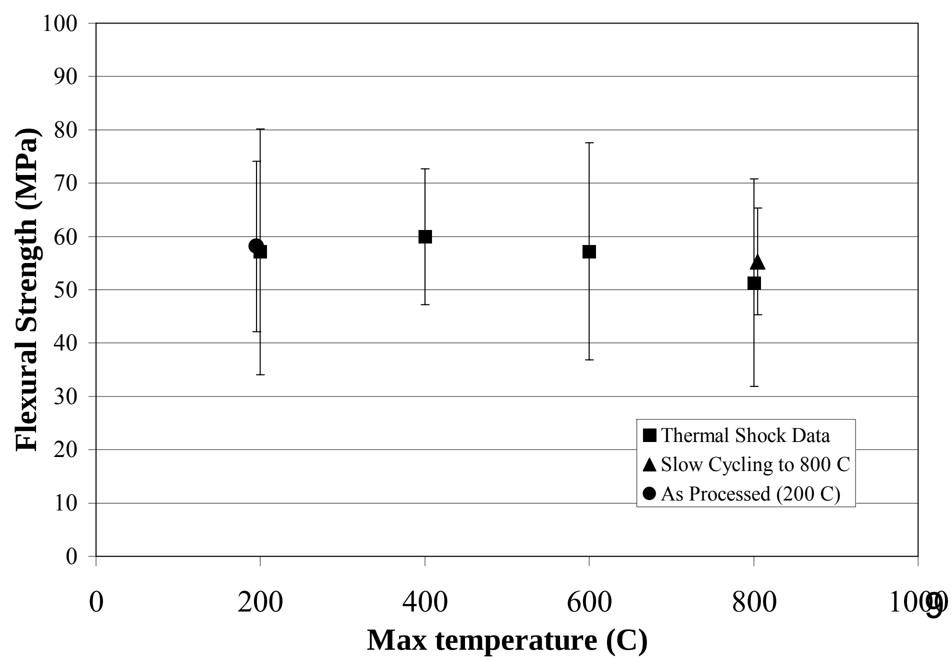
A 5" x 5" L-shaped CERCANAM sample before and after thermal cycling. No degradation was seen after 9 cycles. The same part, after 9 thermal cycles from room temperature to 850°C, was subjected to a thermal shock test (cooling from 850°C to room temperature at ~ 3600°C/hr). The part survived and was intact after the intensive test regimen.

Thermal Cycling/Thermal Shock Resistance of CERCANAM®

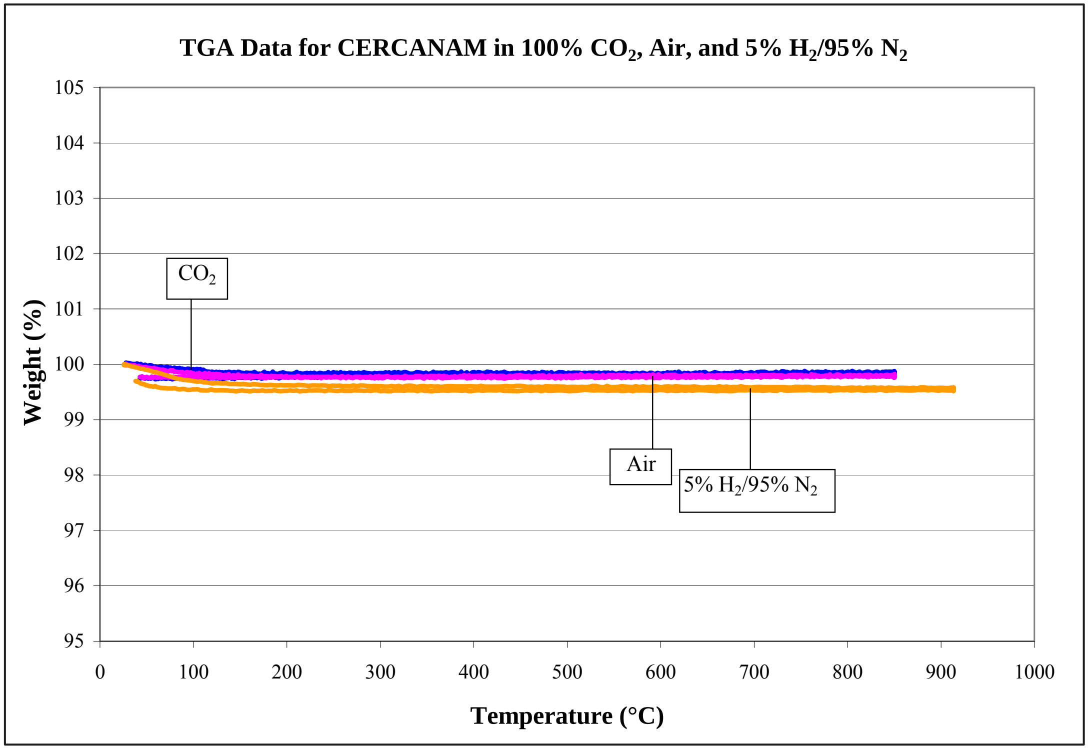
Effect of Thermal Shock on Flexural Strength



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



CERCANAM®
Thermochemical Stability



CERCANAM shows excellent thermal stability in air, CO_2 and H_2. The initial weight loss is due to release of moisture, and is expected.

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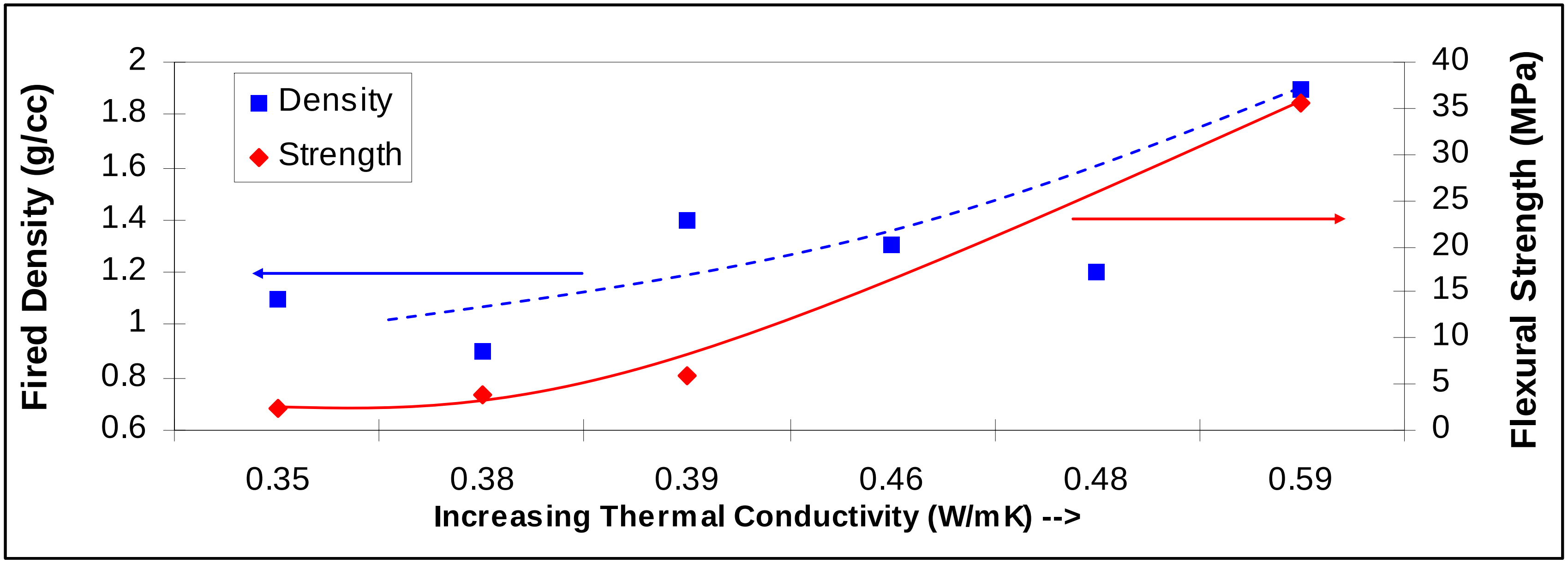
Thermal Conductivity Vs Density/Strength



By tailoring the density (i.e. porosity) of CERCANAM, thermal conductivities lower than 0.4 W/mK can be easily attained which is in the desired target range for fuel cell insulation materials.

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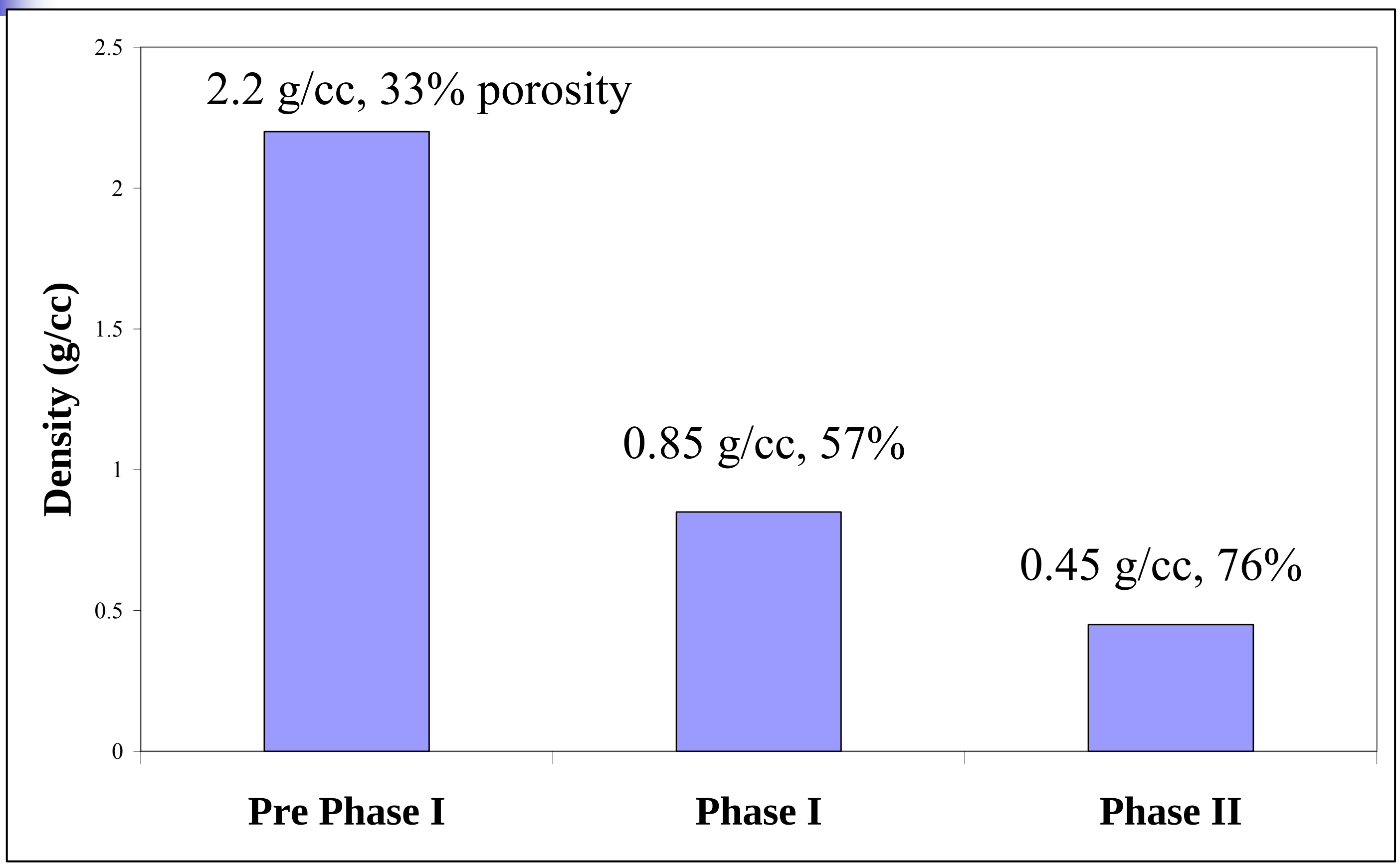
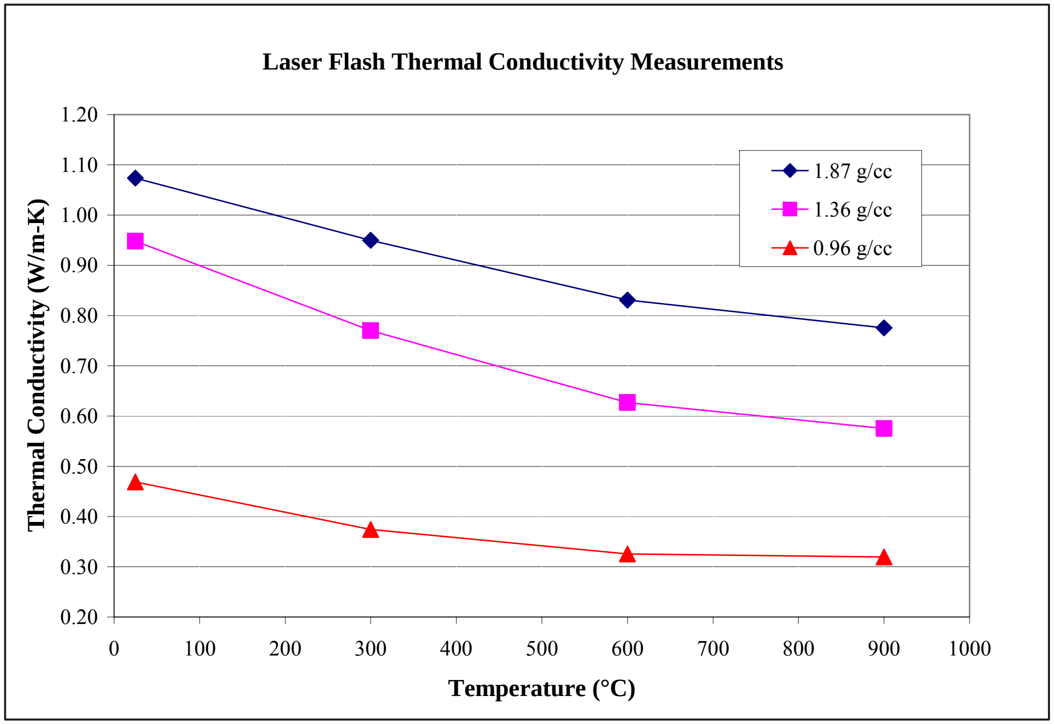
Density Improvements: Lower TC



Lower density → lower thermal conductivity (results awaited)

Laser Flash Conductivity Measurements



Laser flash measurements on CERCANAM compositions confirmed the numbers obtained using the modified guarded hot plate apparatus.

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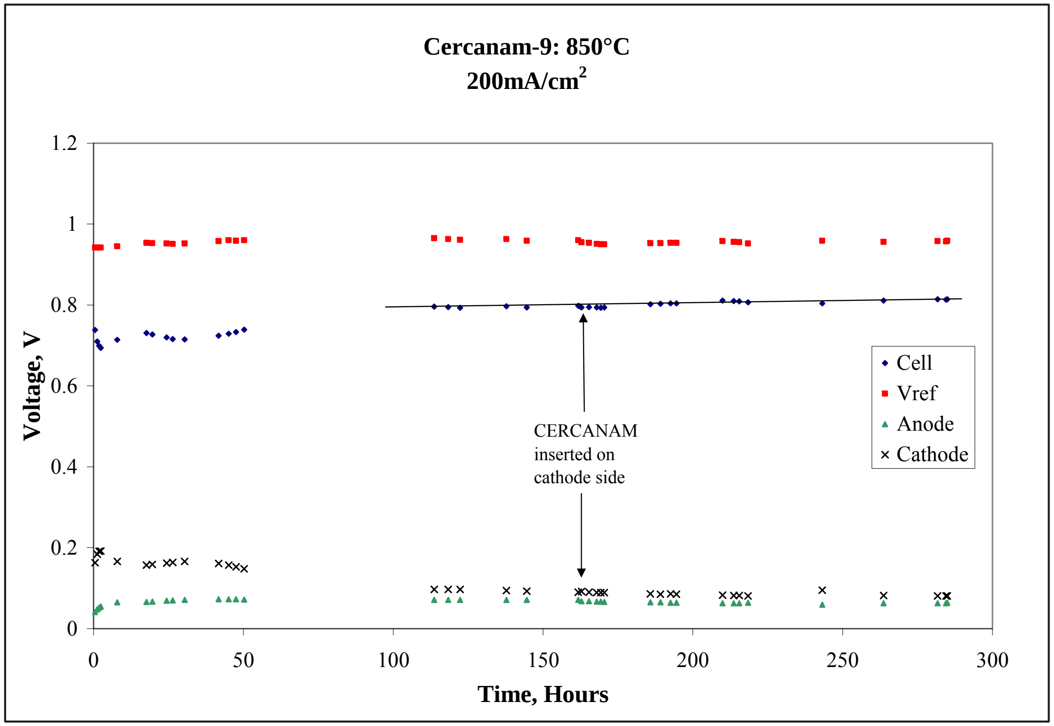
Effect of CERCANAM on YSZ SOFC

- 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).

Cell Voltage vs. Time



No degradation in cell performance was observed with CERCANAM in the air+H_2O stream.

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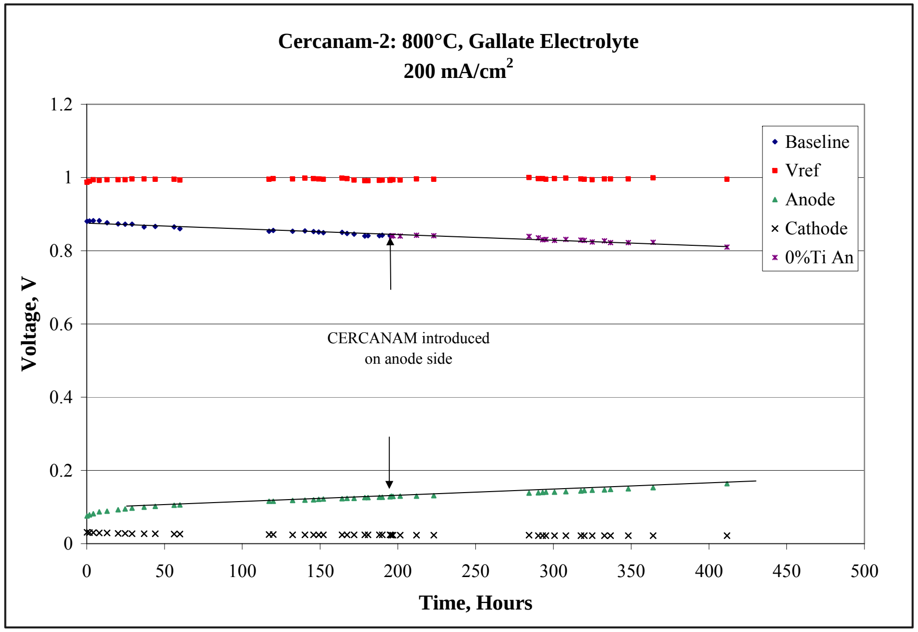
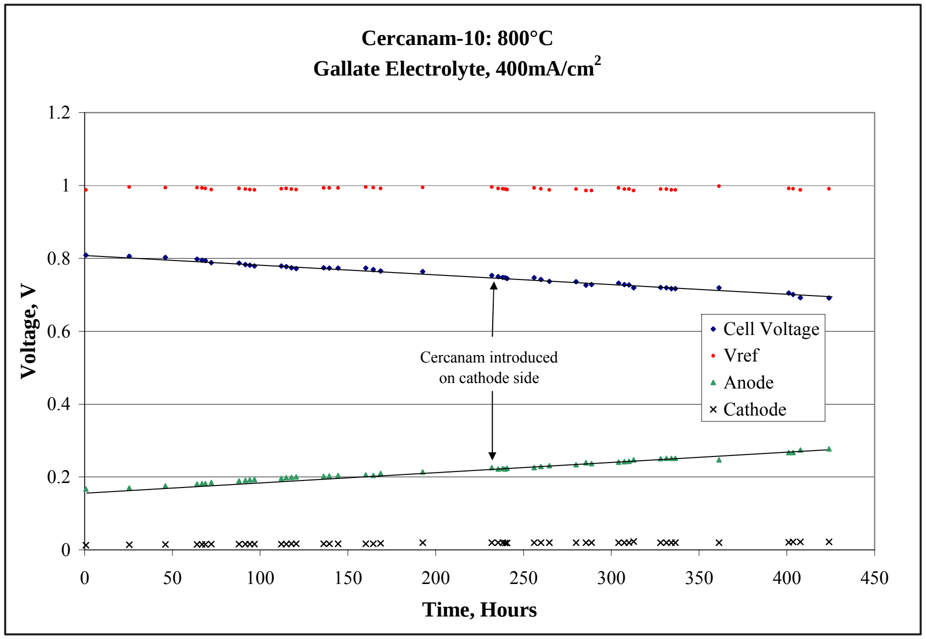
Effect of CERCANAM on Gallate SOFC

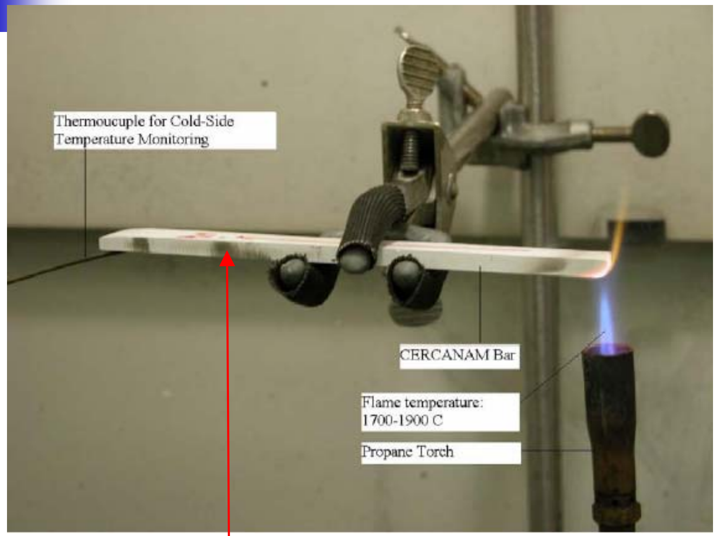
Cell Voltage vs. Time

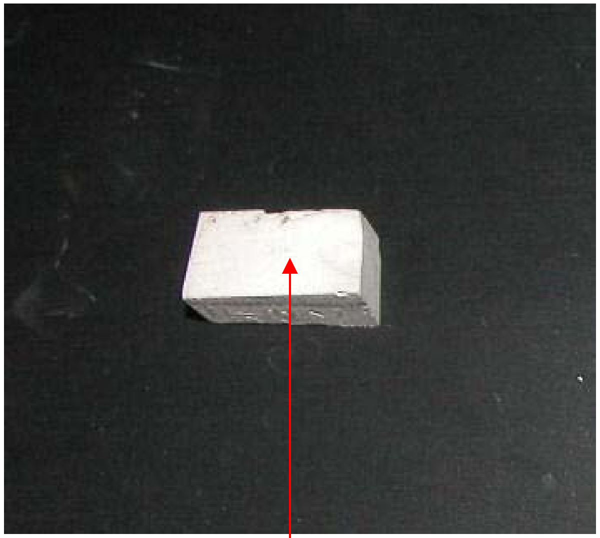




- No effect was observed when CERCANAM was introduced on the air or fuel side of gallate SOFCs.

Thermal Resistance of CERCANAM





CERCANAM can survive severe thermal gradients as shown by this bar exposed to a propane torch (~1800°C) on one side and room temperature on the other side, which did not fail or crack.

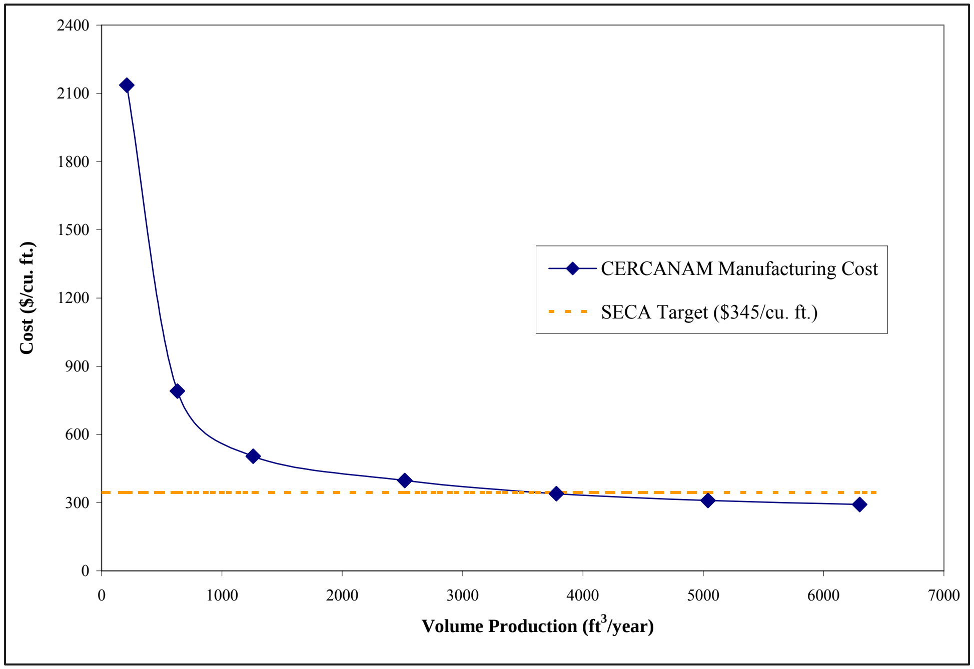
CERCANAM sample exposed to reformed natural gas at 900°C showing no coke deposition in the micropores (i.e. no color change).

Production Cost Analysis

Production Cost

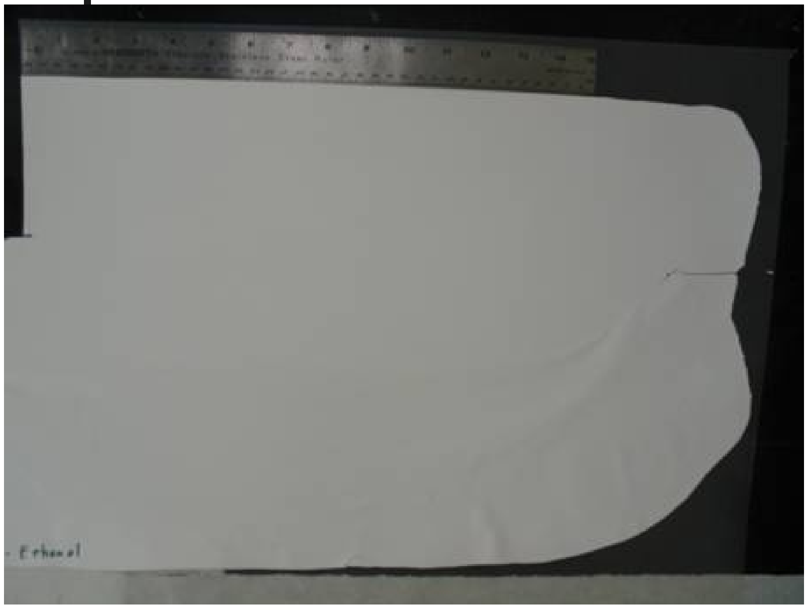
Vs

Production Volume

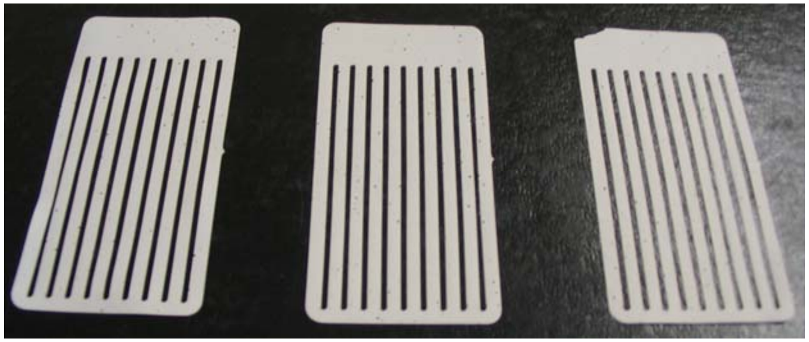


- Raw materials cost at high volume production is $100-125/cubic ft.
- Results indicate that SECA cost targets ($345/cubic ft) can be met at production levels above 3800 ft^3/year.

Process Flexibility Enables Large Volume Production



Complex shape parts can be easily fabricated by a proprietary net size processing technique



- Large volume production can be easily achieved using simple processes like continuous thick-tape casting with laminated structures to get desired thickness

- Channels and micro-features can be inbuilt into the structure (for use as manifolds for cooling or gas flow)

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