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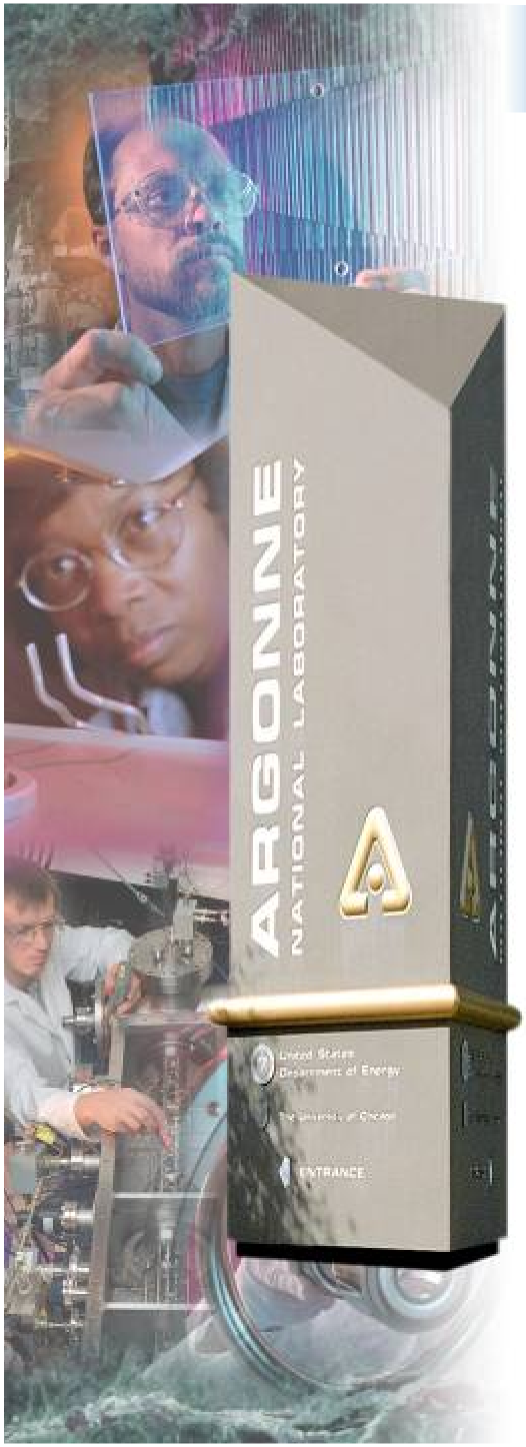

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Recent Progress on the Development of TuffCell, a Metal-Supported SOFC/SOEC

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THE UNIVERSITY OF CHICAGO

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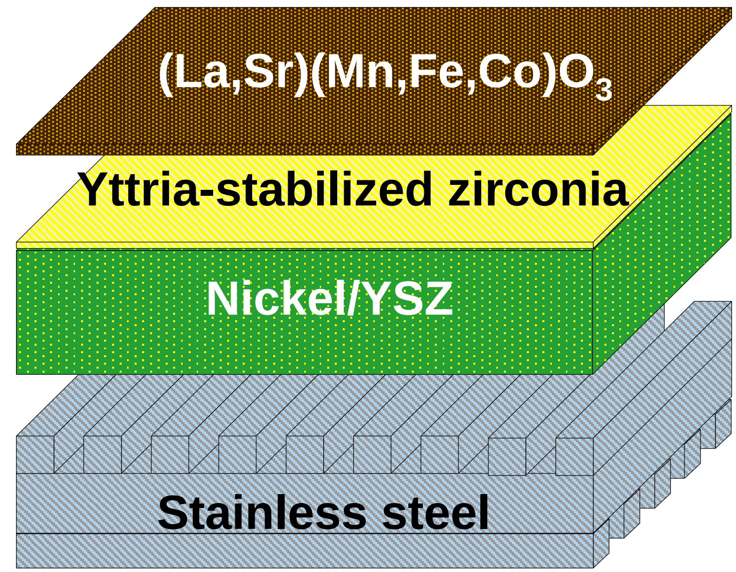
SOFC challenges

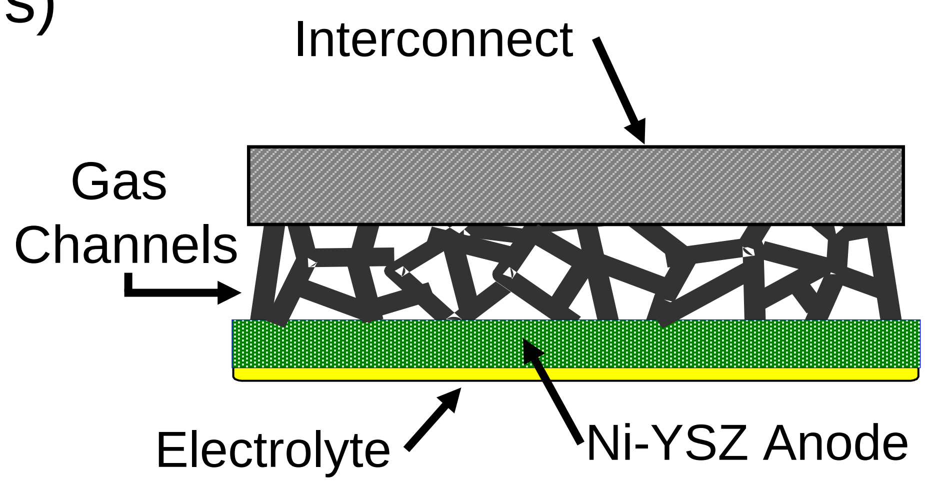
- Cell development
  - Low temperature cathodes
  - Sulfur/redox tolerant anodes
  - Materials cost
- Stack building
  - Planar seals
  - Ohmic contact
  - Brittle ceramics
  - Manufacturing cost
- Stack operation
  - Slow startup/cool down
  - Broken cells
  - Degradation – corrosion, interaction, instability



Anode-supported SOFC

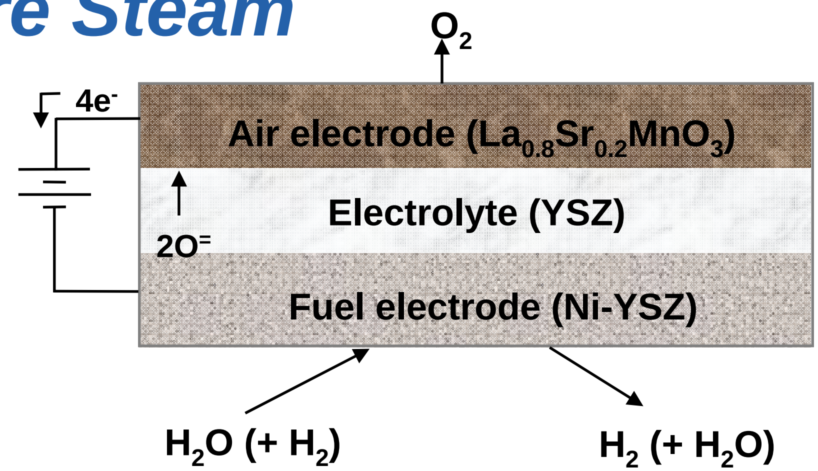
Argonne design concept to resolve SOFC challenges

- Co-sinter repeating units (cells) as building blocks to improve mechanical and electrical properties
- Fabricate and sinter cell components using powder metallurgy techniques
- Seal repeat units with gasket or co-sinter in place
- Minimize thickness of expensive ceramic-containing layers (anode & electrolyte)
- Eliminate manufacturing steps to reduce cost



TuffCell

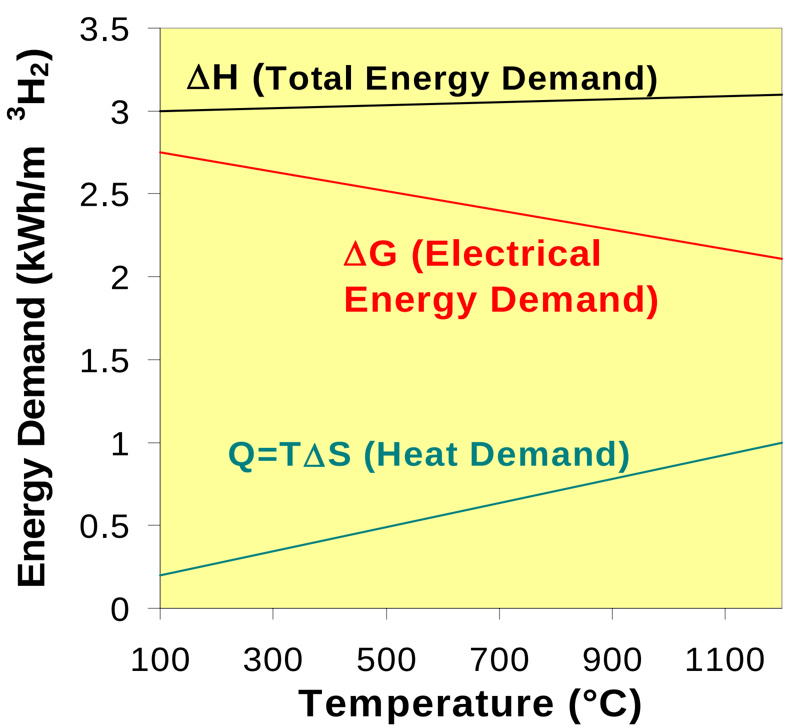
TuffCell in High Temperature Steam Electrolysis (HTSE) mode



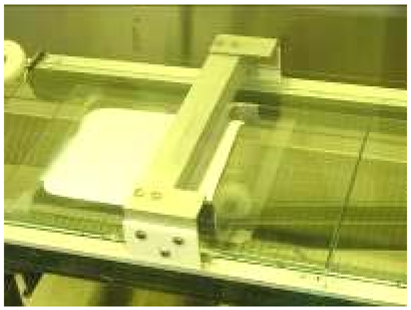
- Reverse cell polarization and gas feed composition to make hydrogen from steam

- High temperature reduces electrical energy demand

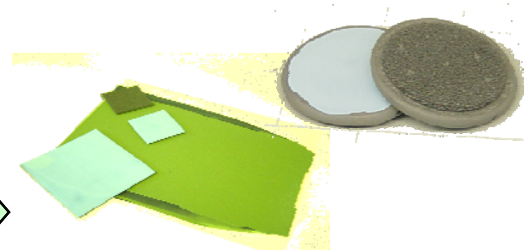
- Heat and electricity obtained from 4th Generation Gas-cooled Nuclear Reactors



TuffCell fabrication features



Tape cast cell layers



Laminate and cut tapes & foam

Co-sinter process

Slurry-coat cathode

- Multi-layer tape casting
- Slurry-coated foam gas flow fields
- Controlled atmosphere, high temperature co-sintering process
- *In situ* cathode sintering

Cross-section of TuffCell laminate

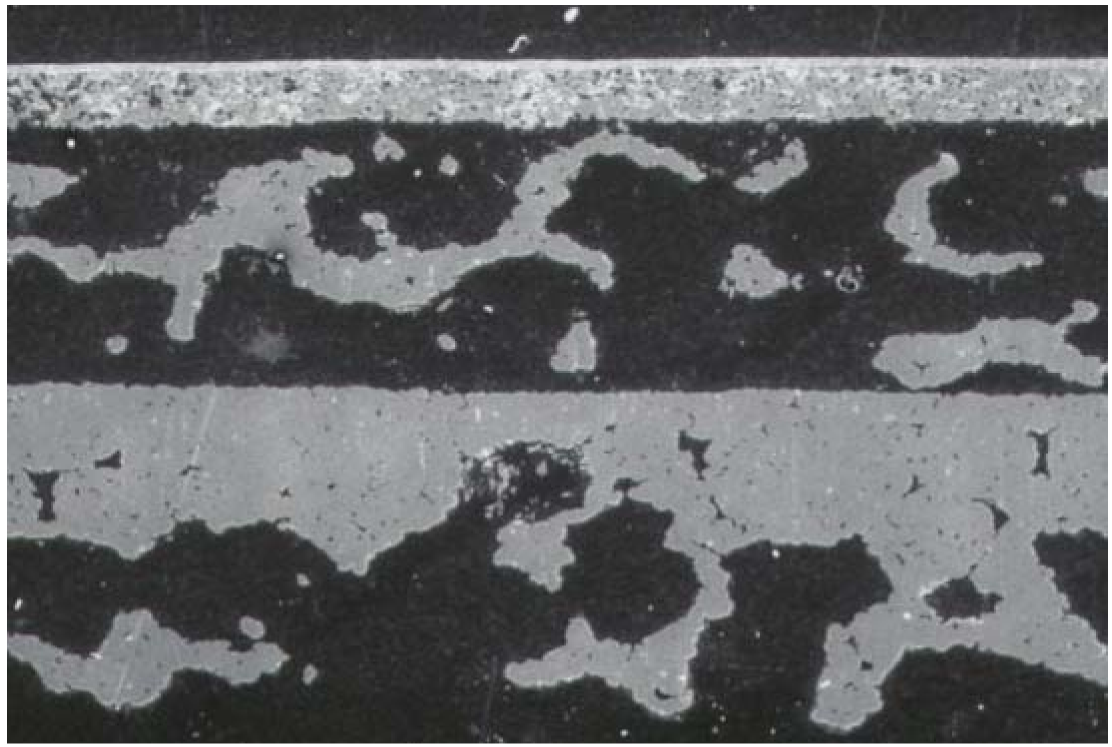
TZ-8Y Electrolyte (15µm)

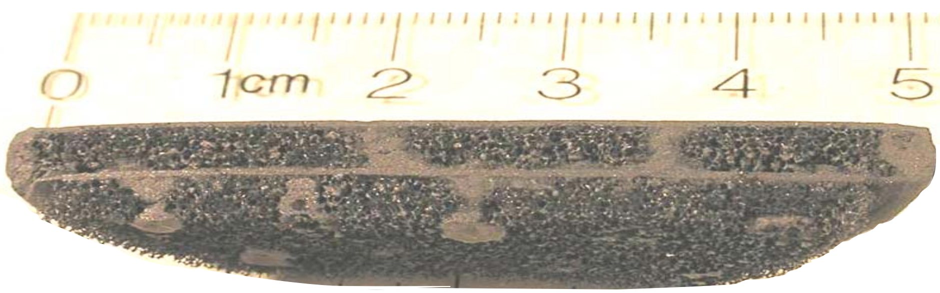
Ni/TZ-8Y Anode (200µm)

434- Stainless steel
Fuel flow field (1000µm)

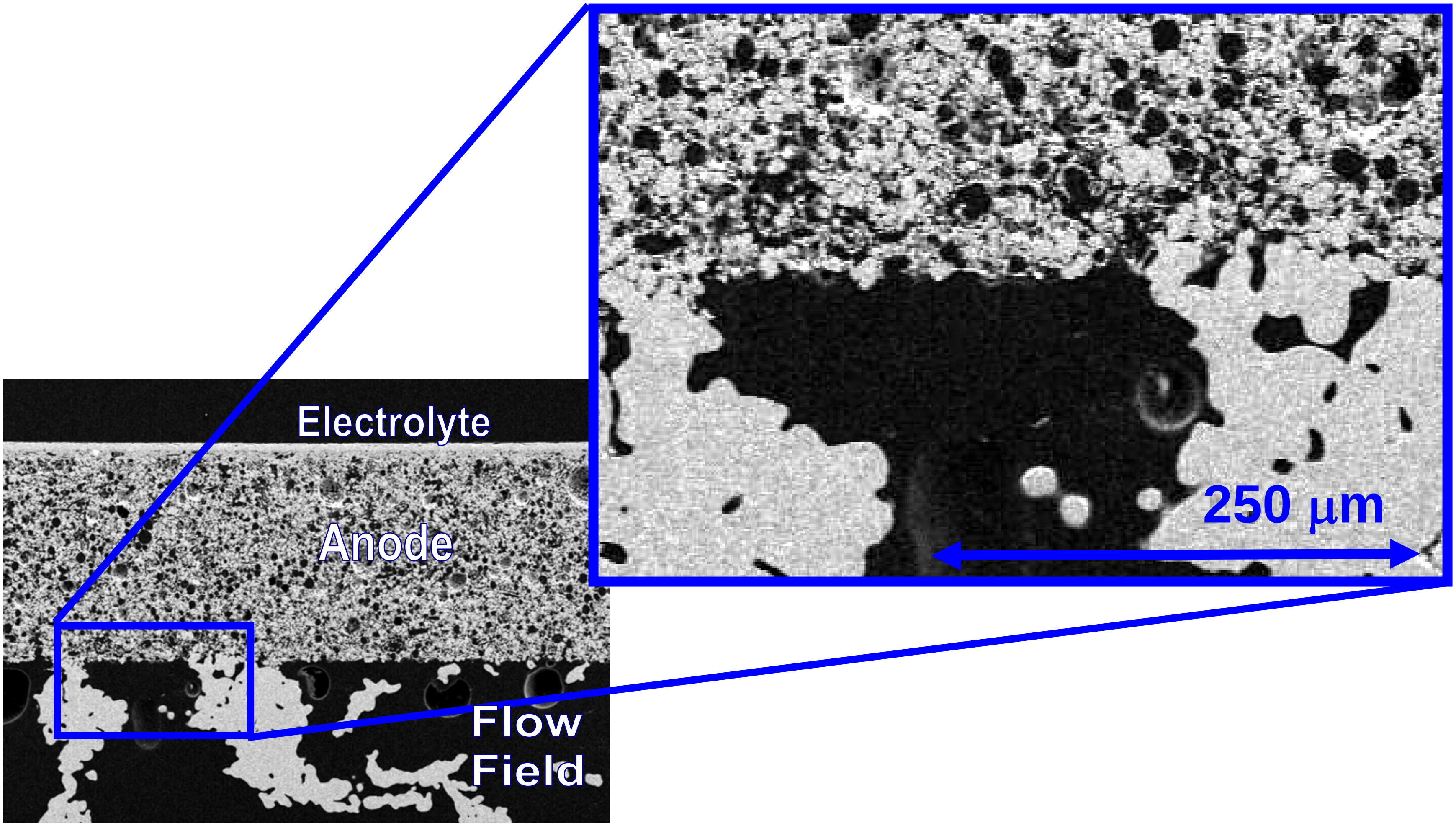
434-Stainless steel
Bipolar plate (200µm)

434- Stainless steel
Air flow field (800µm)



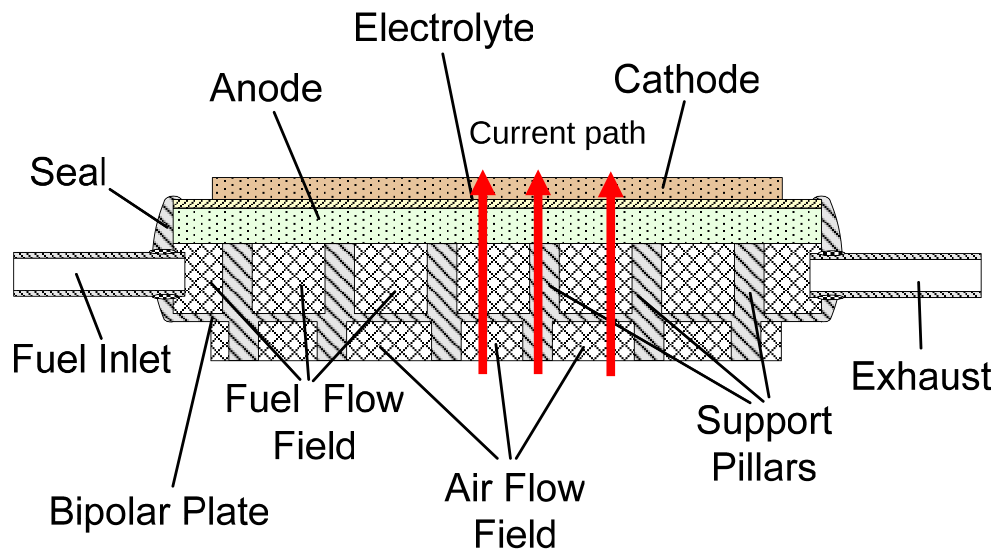


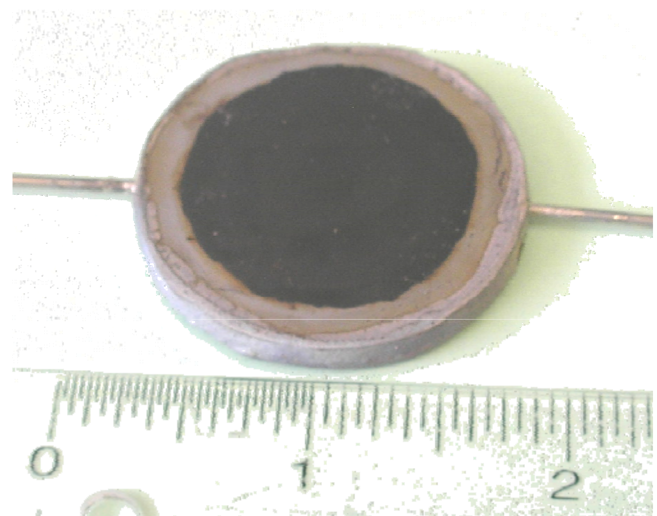
Functional layers of TuffCell are well-sintered together



New seal concept simplifies stack building

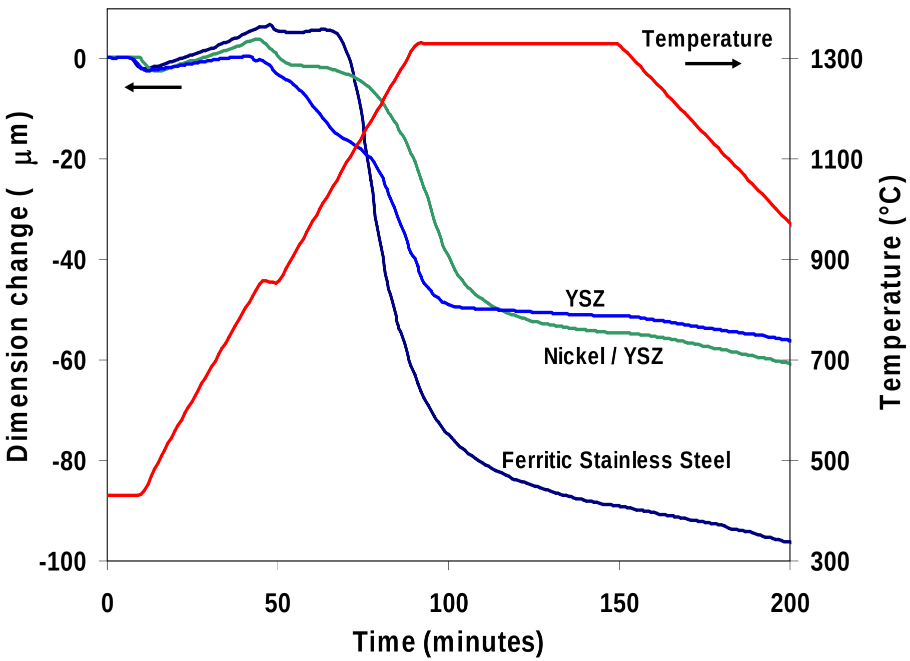
- Anode chamber sealed with interconnect metal
- Feed and exit tubes brazed into edge of stack unit
- Cells stack together as easily as flashlight batteries



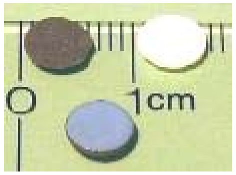


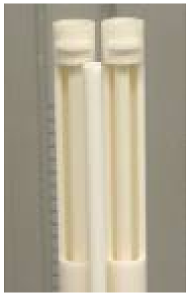
Co-sintering process developed using dilatometry

- Dual-sample testing
- Automatic atmosphere control
- Controlled sample load
- 6-mm dia x 0.5 mm thick tape-cast disks
- Single and multi-layer laminates



Dilatometer





Tape-cast disks

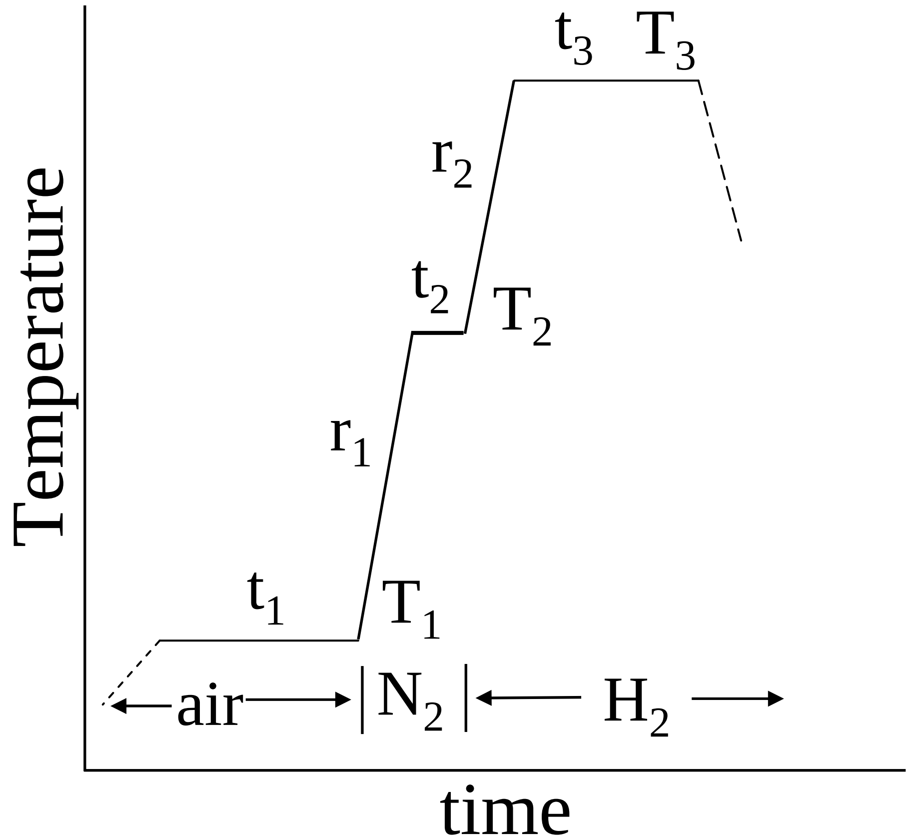
Dual sample

Atmosphere Control

Sintering parameters: temperature, time, heating rate, air & hydrogen flow

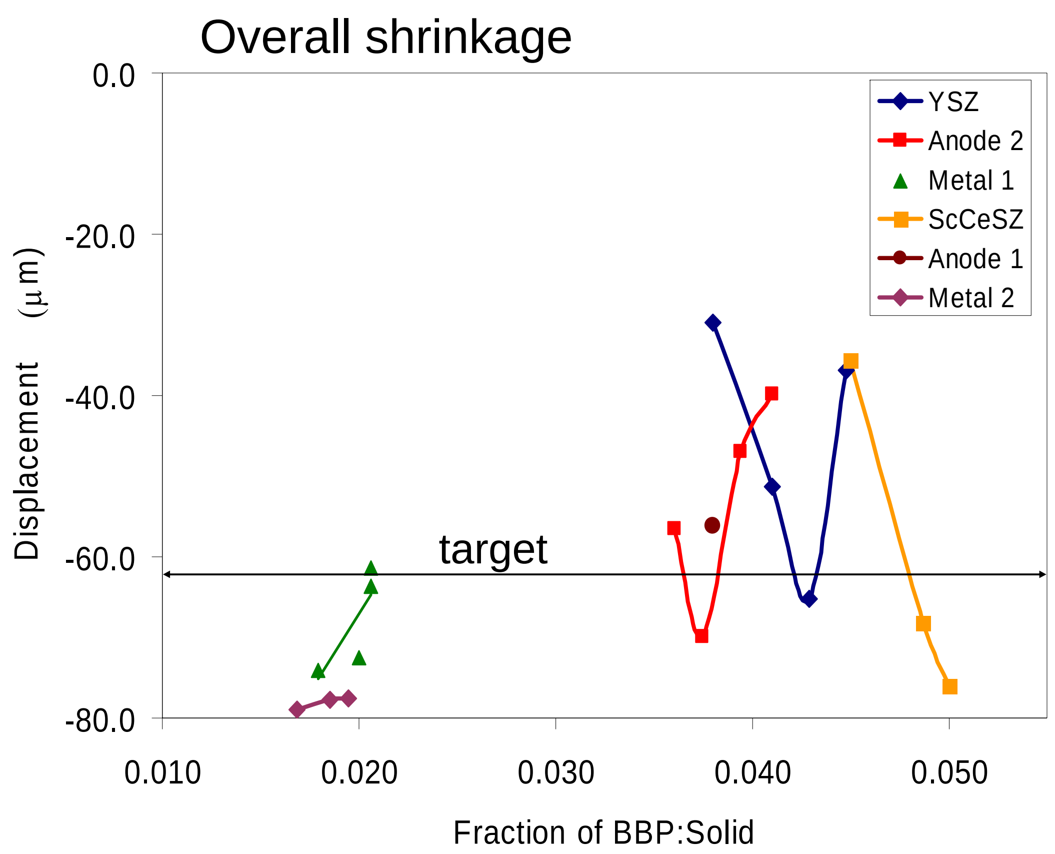
Co-sintering Requirements:

- Match overall shrinkage for each layer
- Match onset of sintering for each layer
- Dense electrolyte, interconnect & seals
- Porous Ni/YSZ anode
- Rigid & open gas flow-fields



Matching overall sintering shrinkage: Effect of plasticizer ratio in tape-cast composition

- Fixed binder content
- Varied plasticizer to solids ratio
- Determined overall shrinkage using dilatometry

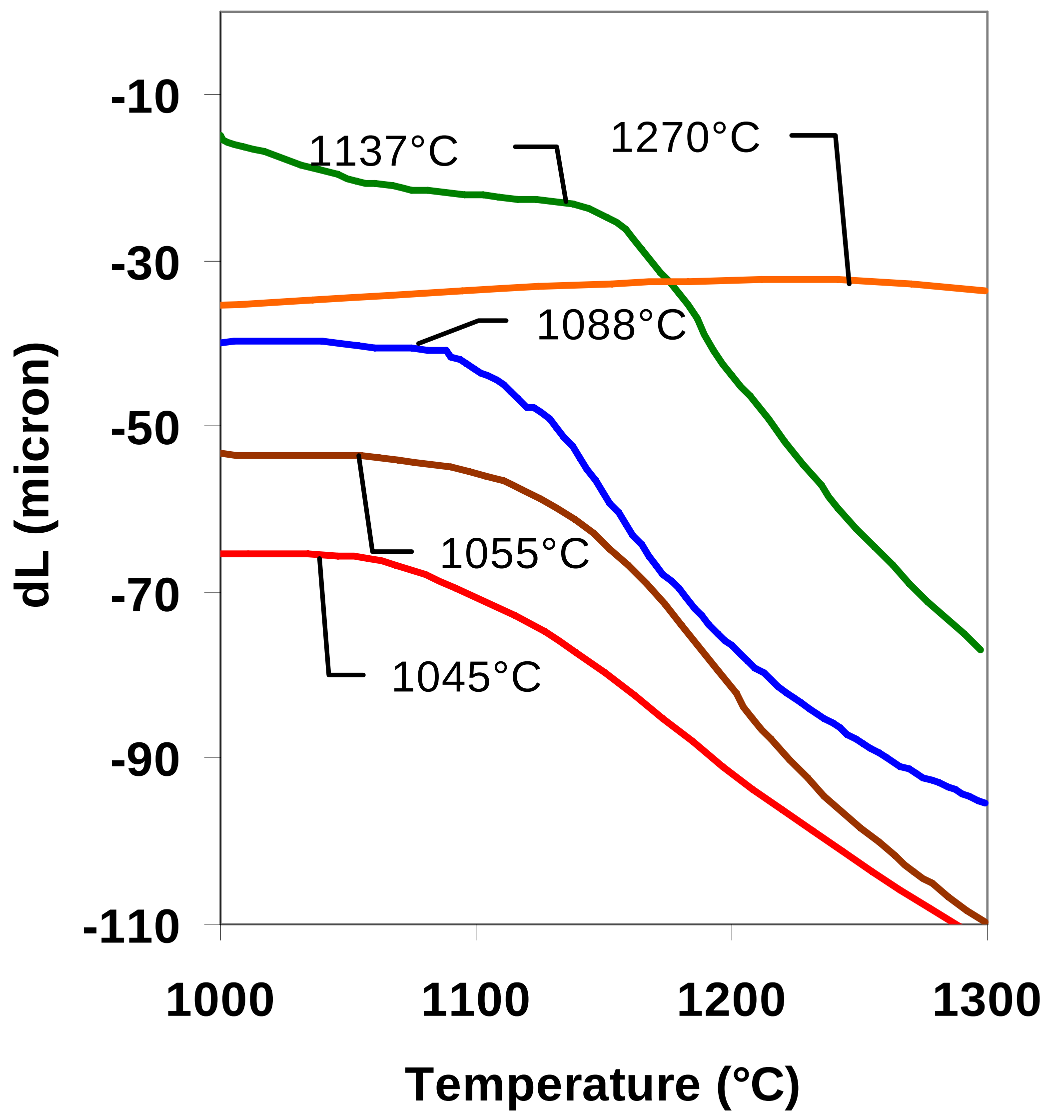


Controlling onset of sintering temperatures for 434-SS

- 434-SS normally sinters at 1120°C
- YSZ sinters at 1300°C
- NiO shrinks upon reduction to Ni

By adjusting sintering parameters:

- 434-SS sintering onset can be offset by ± 100°C



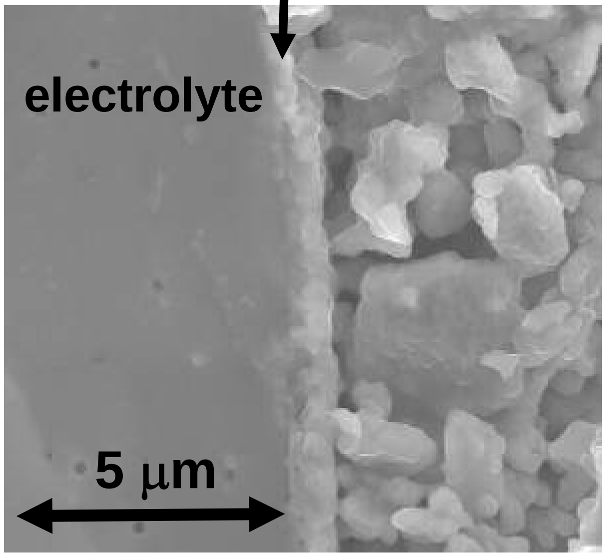
TuffCell air electrode requirements

- Low-temperature application–
  Sinter *in situ*
- High performance materials–
  Cobaltites, Ferrites
- Long-term stability

Approach:

- Ceria interlayer
- Thin (<1um), dense active electrode
- Thick porous current collector
- Polymer precursor gels
- Low temperature *in situ* sinter porous cathode

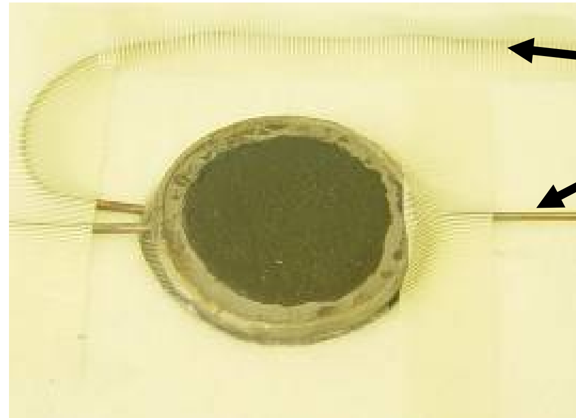
ceria interlayer
active cathode layer



Porous air electrode

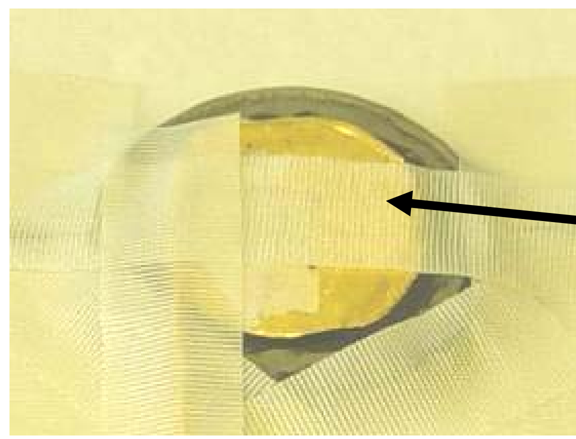
Cell Testing

- Simple gas & electrical connections
- Flexible air flow directions:
  - *Co-flow*
  - *Cross-flow*
  - *Counter-flow*
- Simple stacking requirements



air feed

fuel feed

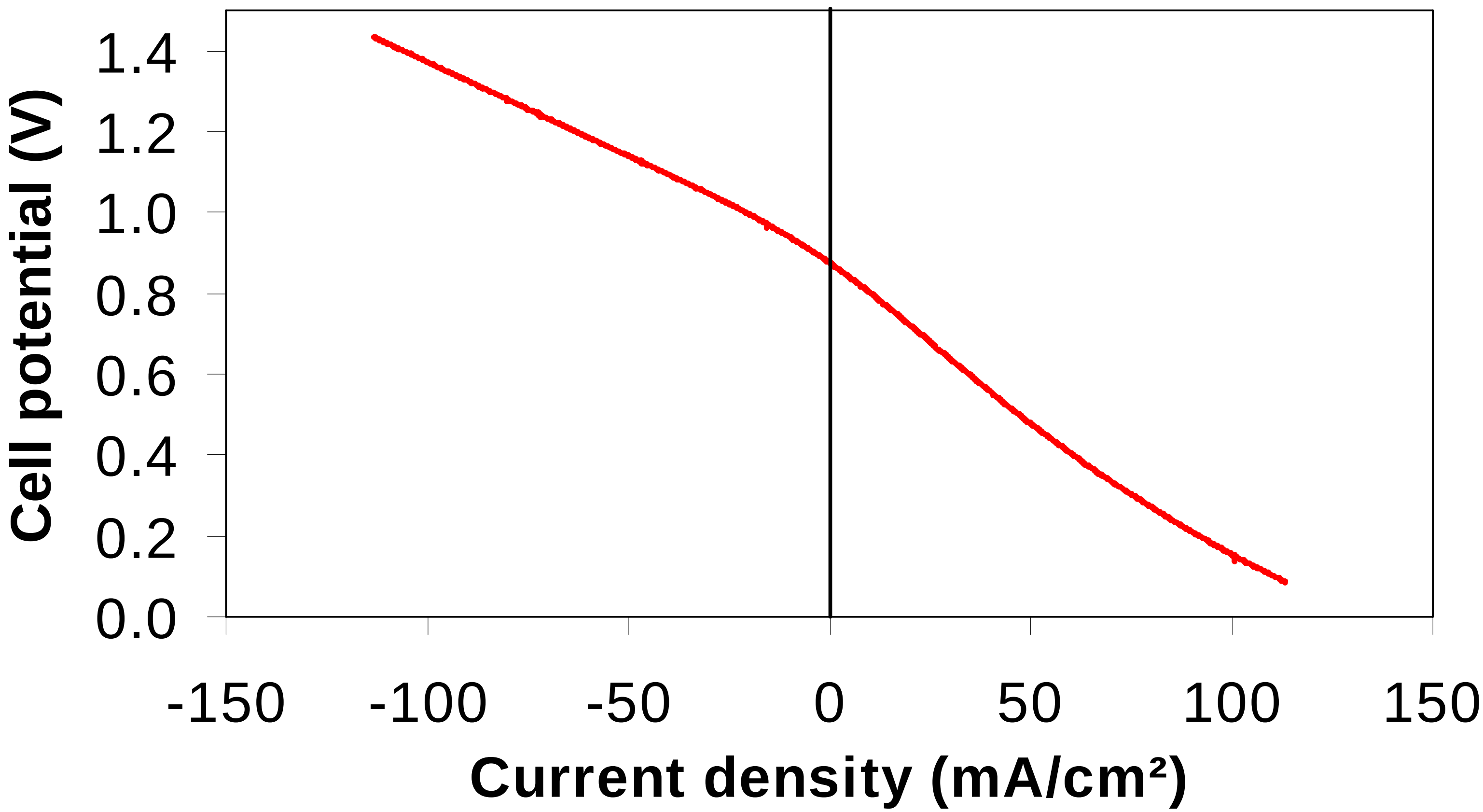


current collector

Current Status of Cell Polarization Behavior

- Testing single cells in SOFC and SOEC modes

798°C
300 sccm H2, 3% H2O
400sccm air



Continuing Work

- Improve single cell performance to >300 mW/cm^2 by modifying air and fuel electrodes
- Demonstrate cell/stack thermal cyclability
- Provide sample cells to interested parties
- Demonstrate long-term cell/stack performance tests
- Transfer technology for scale-up and system integration

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