Solid Oxide Fuel Cell Research at Argonne National Laboratory

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Task areas

- Low-temperature cathode materials
- Sulfur-tolerant anode materials
- Metallic interconnect (bipolar) plates

Low-Temperature Cathode Development

Overview: why new cathodes

- LSM is a poor cathode material at <900^{o}C, even as LSM/YSZ composite
- Need to develop a mixed conducting material to achieve better power densities at $\leq$800^{o}C
- Options:
  - replace Mn in LSM by Co, Fe, or Ni
  - move to differently structured materials
- La(Sr)FeO_3 (LSF) has proven to be the most compatible and best performing cathode with YSZ

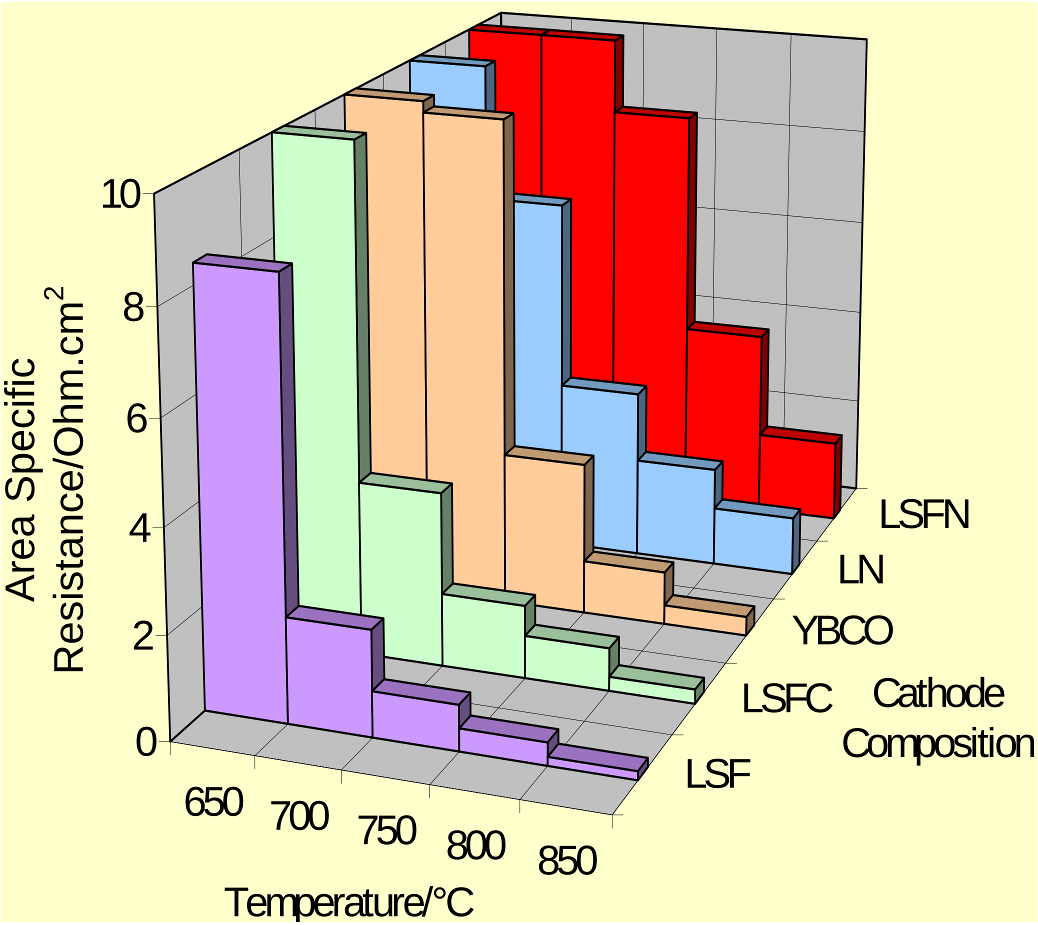
Low-Temperature Cathode Development

Perovskite-based cathodes

Composition	Electronic Conductivity (Scm^{-1}) at 800°C	Ionic Conductivity (Scm^{-1}) at 900°C
$La_{1-X}Sr_XCoO_3$	1000-2000	8×10^{-1}
$La_{1-X}Sr_XFeO_3$	400-500	1×10^{-2}
$La_{1-X}Sr_XNiO_3$	500	-
$La_{1-X}Sr_XMnO_3$	100-200	10^{-7}
$La_{1-X}Sr_XCrO_3$	<100	$<10^{-7}$

Low-Temperature Cathode Development

Area-specific resistances on YSZ

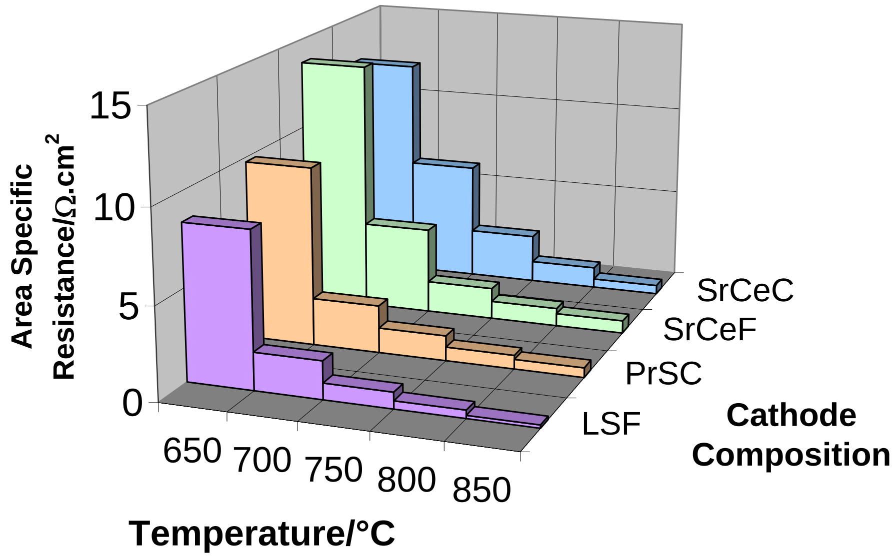


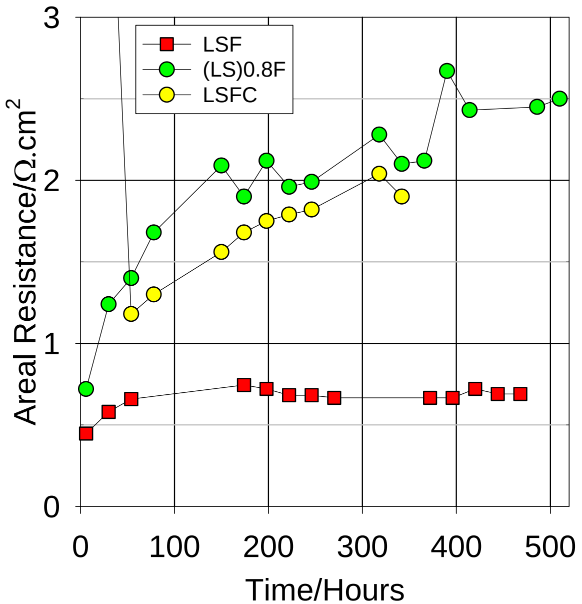
- Ferrite-based perovskites display best performance at all temperatures
- Layered structures (YBCO) show good performance at $\geq 850^{o}C$ but high activation energies preclude use at lower temperatures

Low Temperature Cathode Development

Advanced cathode materials

- Accomplishments
  - Identified Sr-doped lanthanum ferrates as the most promising candidate cathode materials
  - Verified stable performance to 500 h

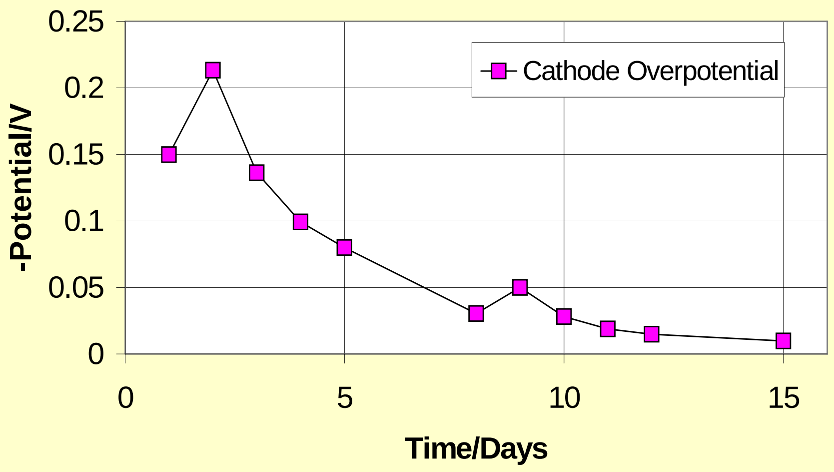


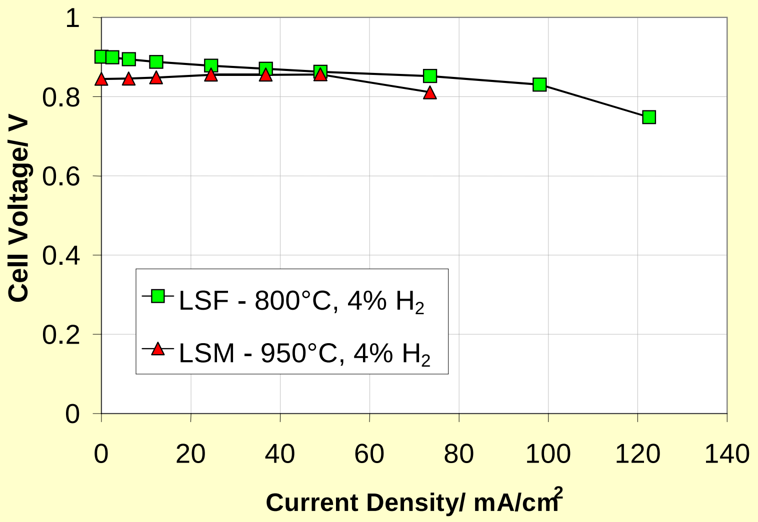


Low-Temperature Cathode Development

Polarization curves for $La(Sr)FeO_3$ on YSZ

- Current conditioned for ~330 h at 250 mA cm^{-2}, 800ºC
- Overpotentials decreased with time over the 16 days
- Values for LSF at 800ºC are similar to LSM at 950ºC





Sulfur-Tolerant Anode Materials

Overview: why new anodes

- Sulfur species are present as a contaminant or an additive in the various conventional fuels*:
  - Natural gas: 20 ppm S by volume
  - Gasoline (future): 30 ppm S by weight
  - Diesel (future): 30 ppm S by weight
- Corresponding S content of reformate (by volume):
  - Natural gas: 10-14 ppm
  - Gasoline/Diesel: 3- 5 ppm
- These levels are sufficient to degrade the performance of the conventional Ni-YSZ anodes

*Synthetic fuels (e.g., methanol, F-T diesel) have very low to zero S

Sulfur-Tolerant Anode Materials

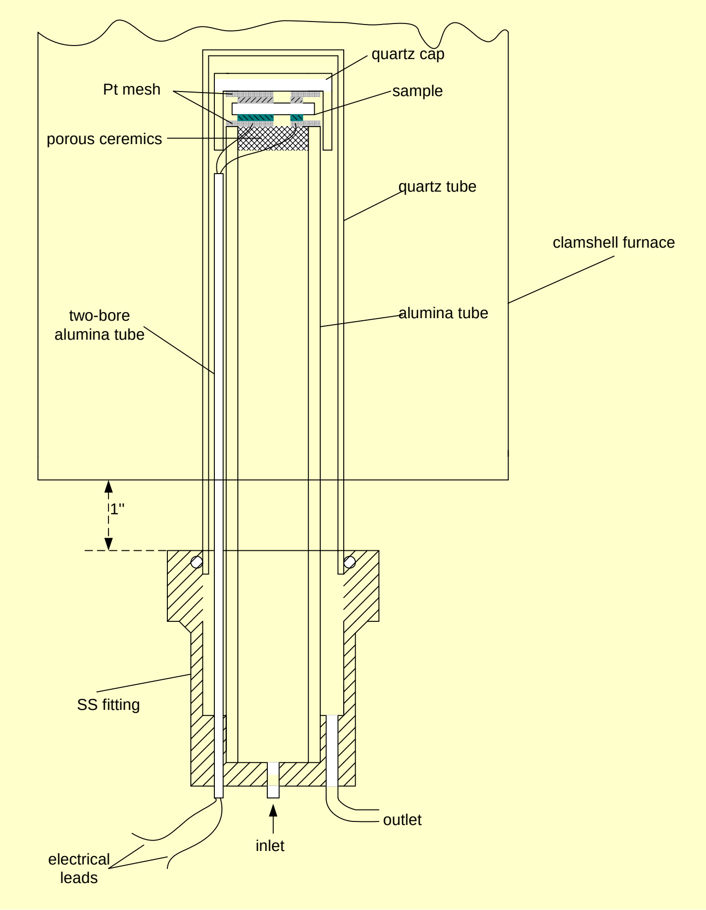
Approach

- Modify conventional anode material with an additive that has suitable redox chemistry
  - additive captures H_2S in preference to Ni; the H_2S is subsequently oxidized to SO_2
- Replace the Ni in Ni-YSZ with other metal or alloy active for electrooxidation of H_2 but resistant to poisoning by H_2S
- Investigate new classes of materials based on carbides and/or sulfides

Sulfur-Tolerant Anode Materials

Status

- Several candidate anode materials have been coated on commercial YSZ disks for half-cell tests
- Tests are in progress with simulated reformate containing 0, 5, 30, and 100 ppm H_2S (by volume)

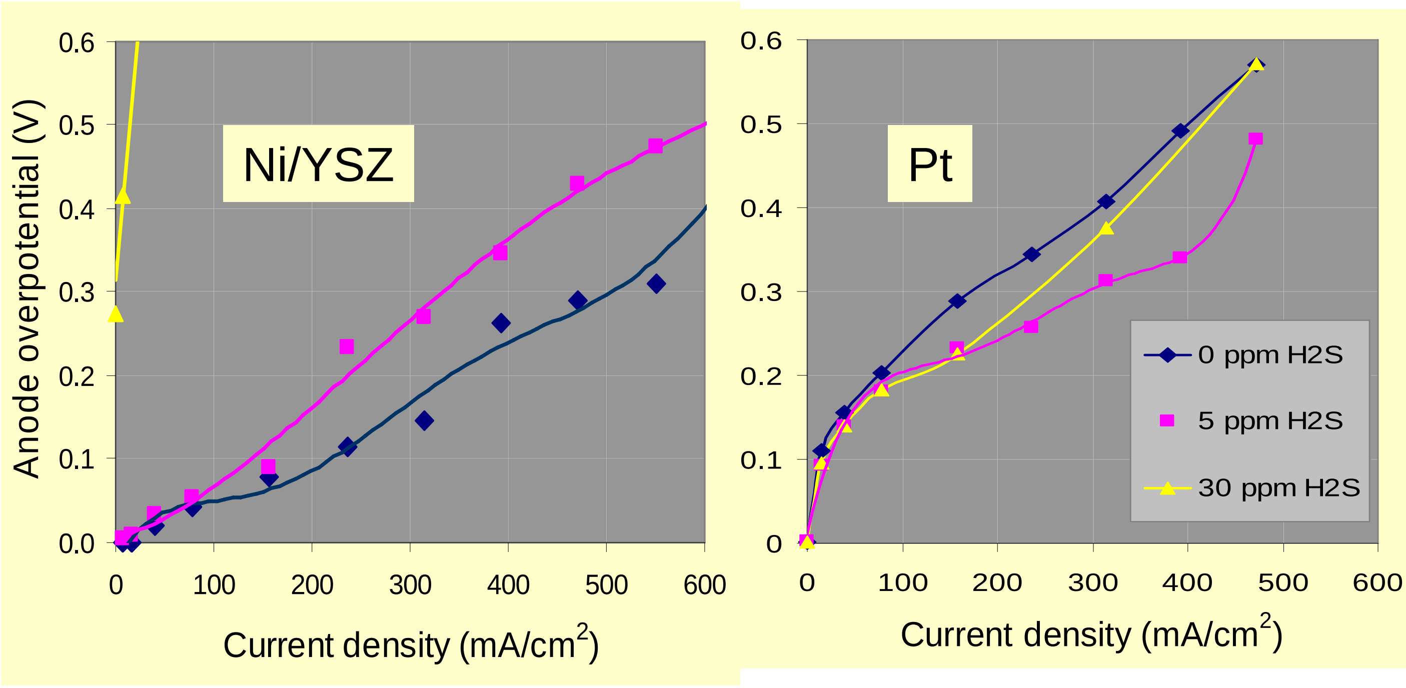


Test Apparatus Schematic

Sulfur-Tolerant Anode Materials

Testing readily verifies sulfur poisoning

- Accomplishments
  - Prepared several half cells with candidate materials
  - Initial tests show severe poisoning of Ni-YSZ by H_2S at 5-30 ppm, no poisoning of Pt anodes



Overview: materials requirements

- Electronically conductive
- Chemically stable under under both anodic and cathodic conditions
- Coefficient of thermal expansion similar to that of the other fuel cell materials
- Formable (for internally manifolded stack designs)

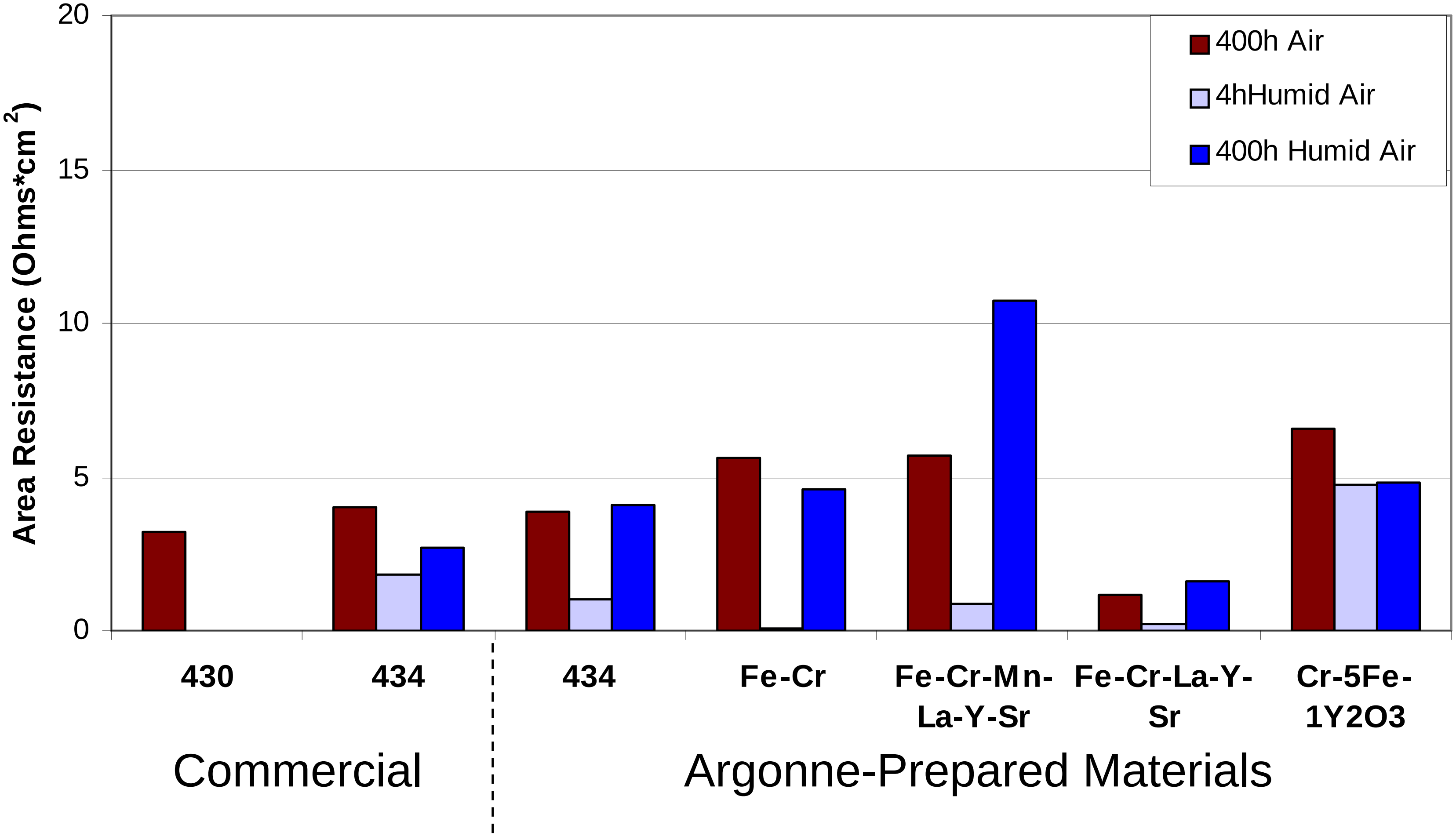
Metallic Interconnect Development

Approach

- Alloys similar to ferritic stainless steels
  - reduce Cr, other elements that can degrade fuel cell performance
  - additives to improve properties and protective scale
- Materials of graded composition to impart optimum chemical stability at each surface
- Novel processing technique can yield almost any desired shape
  - flat, corrugated, textured, functionally graded
  - can incorporate flow fields, internal manifolds

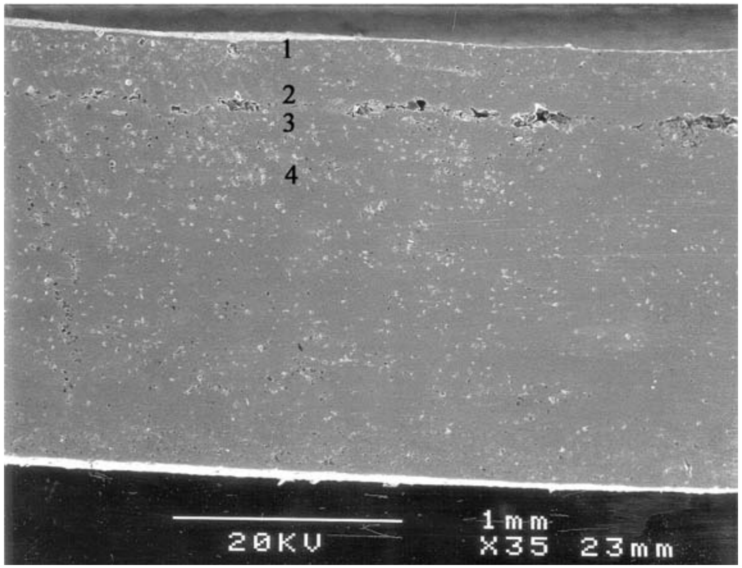
Metallic Interconnect Development

Humid air increases scale resistance



Multi-layer plates are easily formed

- Compositionally graded specimens can be fabricated
- Samples show excellent bonding
- After 400 h at 800ºC, there was no observed elemental diffusion between layers



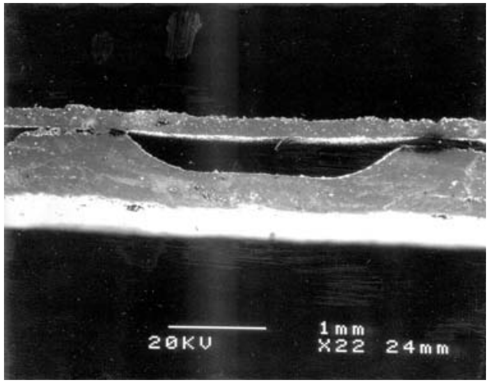
SEM Micrograph of compositionally-graded sample

- 10-Layer specimen
  Two surface layers:
  Fe-Cr-La-Y-Sr alloy
  Bulk: SS Type 434
- Points 1,2: ~1.5 - 2.0 wt% La
- Points 3,4: no measurable La

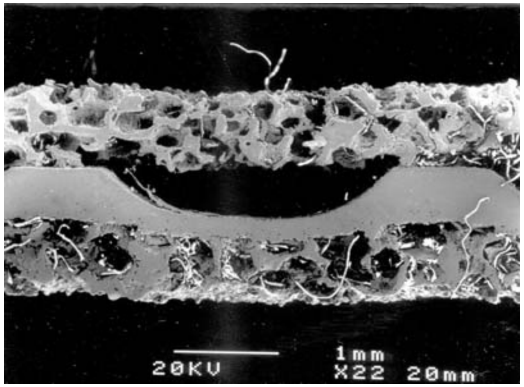
Metallic Interconnect Development

Fabricated laminated structures and shapes

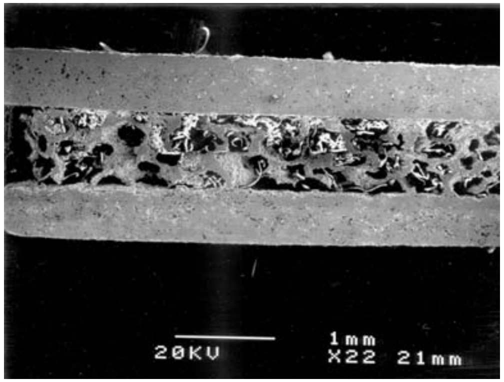
- Accomplishments
  - Investigated novel ferritic steel compositions
  - Successfully formed various shapes and configurations
  - Well-bonded laminates produced routinely



Formed Flow Field
in Dense Material



Formed Flow Field
with Porous Layers



Macroporous Flow
Field

Summary
Future directions

- Micro-engineer the cathode-electrolyte interface to further improve cathode performance
- Evaluate anode materials with 0-100 ppm H_2S in fuel gas
- Characterize oxide scale on metallic bipolar plates for growth rates and electrical conductivity
- Test developed materials in full cell and short stack configurations