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
- Cell, stack, and systems modeling

Low-Temperature Cathode Development

Overview

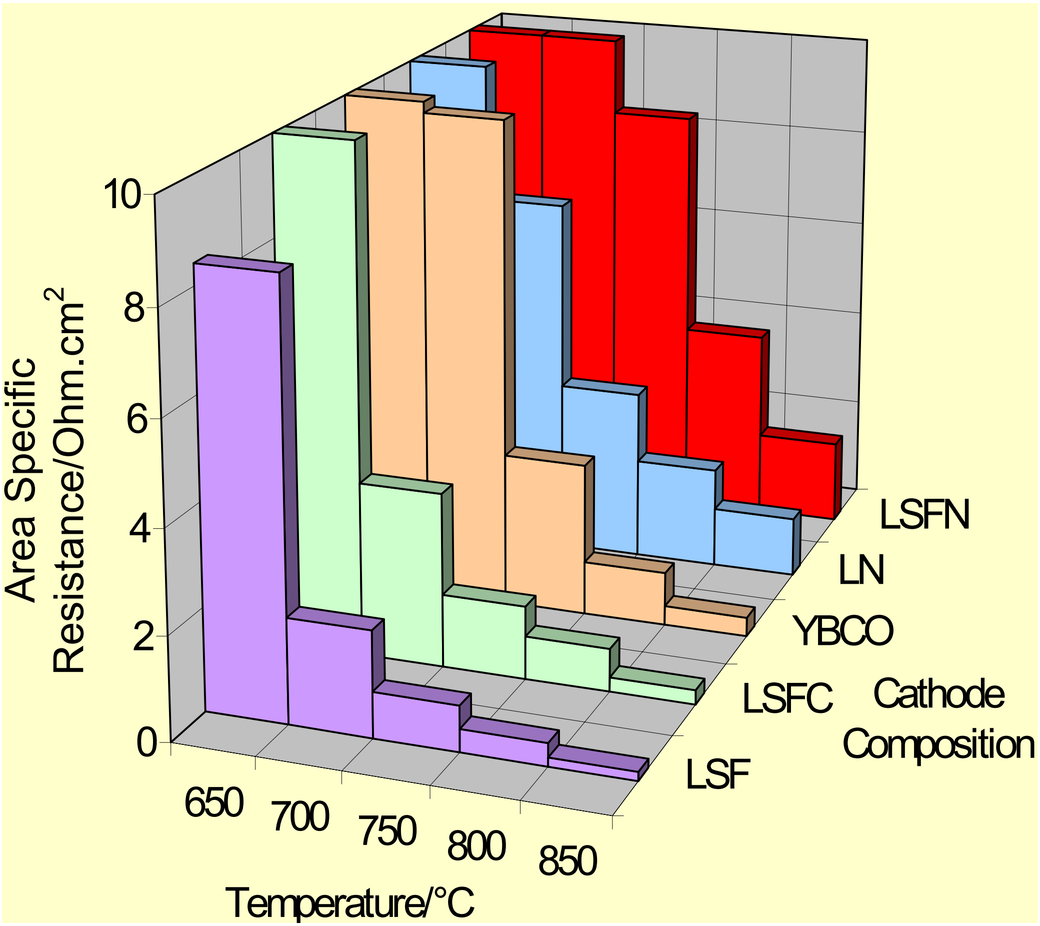
- LSM is a poor cathode material at <900°C, even as LSM/YSZ composite
- Need to develop a mixed conducting material to achieve better power densities at $\leq$800°C
- Options:
  - replace Mn in LSM by Co, Fe, or Ni
  - move to differently structured materials
- La(Sr)FeO_3 (LSF) has proven to be the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



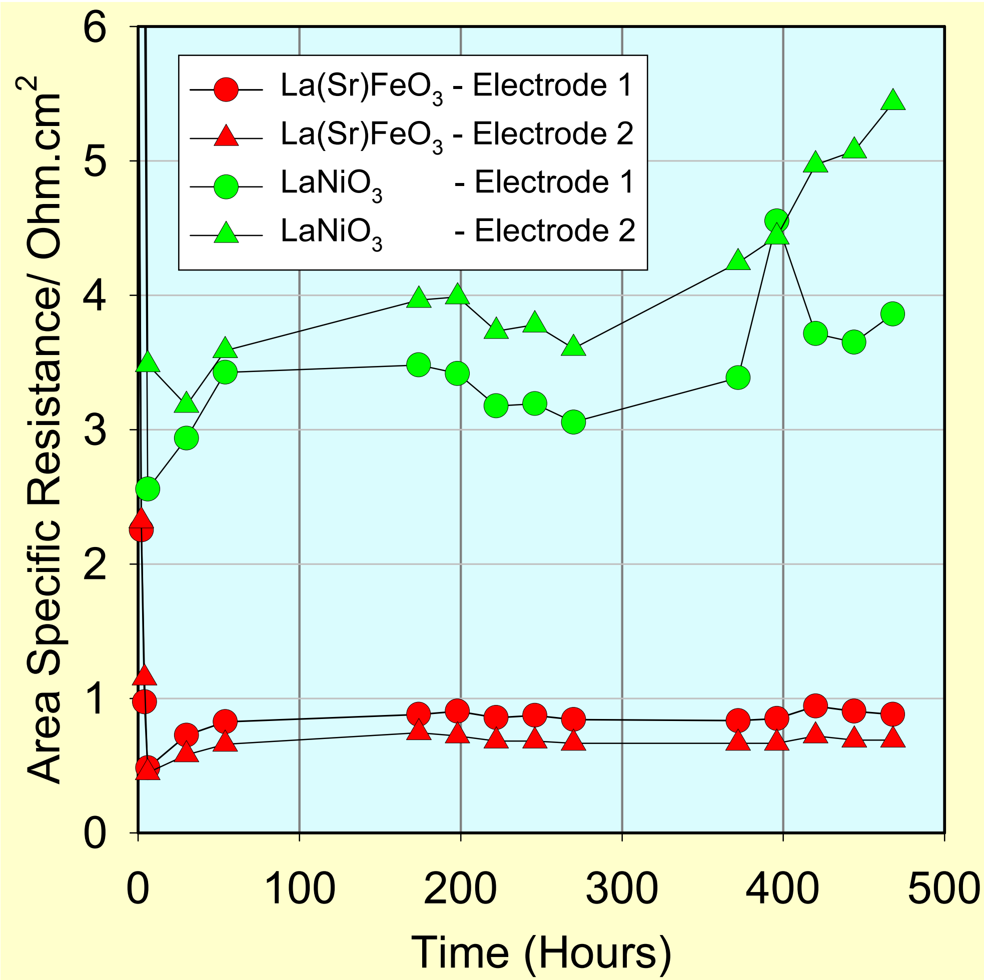
- Ferrite-based perovskites display best performance at all temperatures
  (initial target ASR is <1 Ω cm^2)

- Layered structures show good performance at ≥850°C but high activation energies preclude use at ≤800°C

- Nickelate-based perovskite has potential <u>if</u> the structure can be stabilized when doped

Low-Temperature Cathode Development

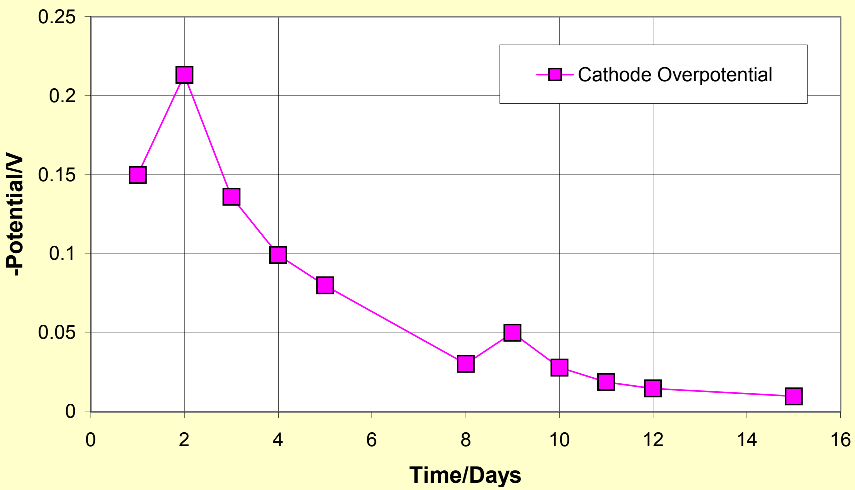
Long-term ASR on YSZ at 800°C

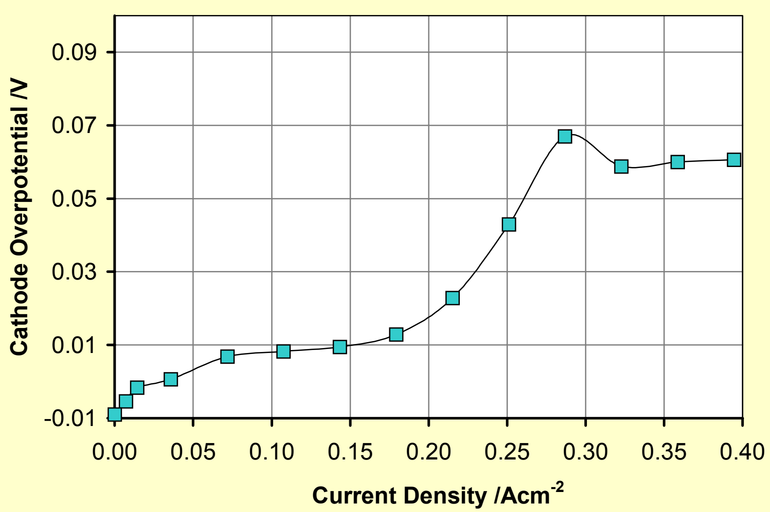


- LSF displays the most stable performance with an ASR of <1 Ω cm^2
- LN has too high an ASR at 800°C

Low-Temperature Cathode Development
Polarization curves for La(Sr)FeO_3 on YSZ

- Current conditioned for ~330 h at 250 mA cm^{-2} at 800°C
- Overpotentials decreased with time over the 16 days
- Values for LSF at 800°C are similar to LSM at 1000°C



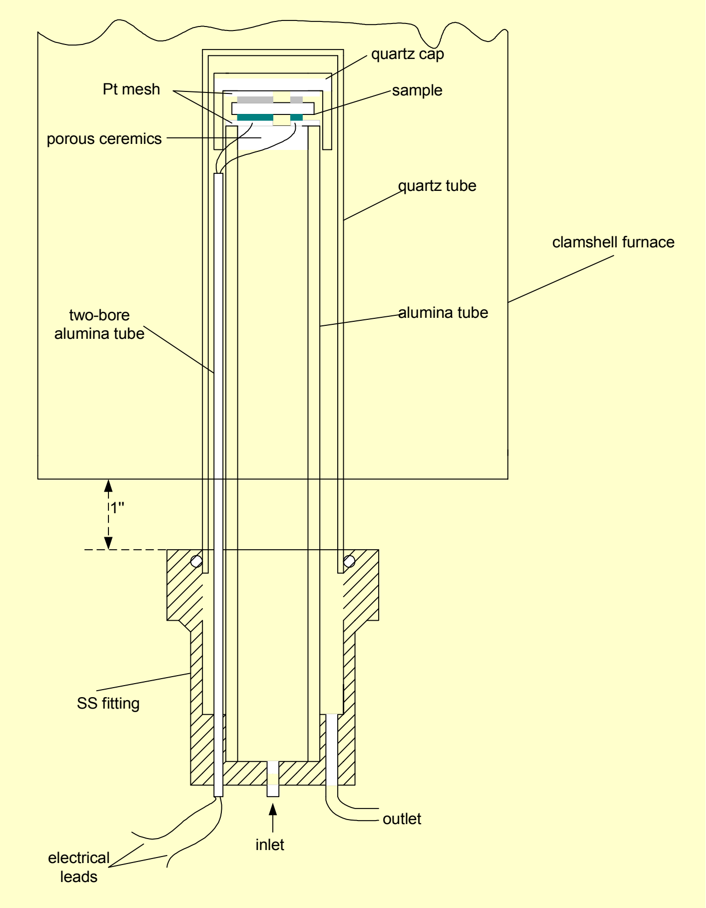


Sulfur-Tolerant Anode Materials
Approach

- 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
- Testing will get underway within the next few weeks with fuel gases containing 0-100 ppm H_2S



Test Apparatus Schematic

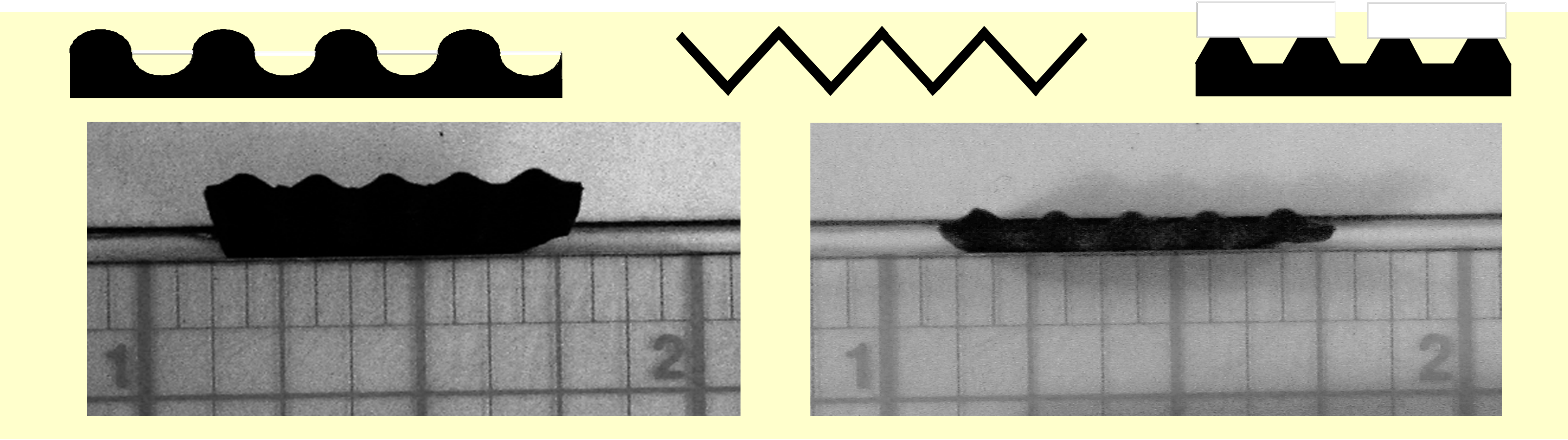
Metallic Interconnect Development

Materials requirements

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

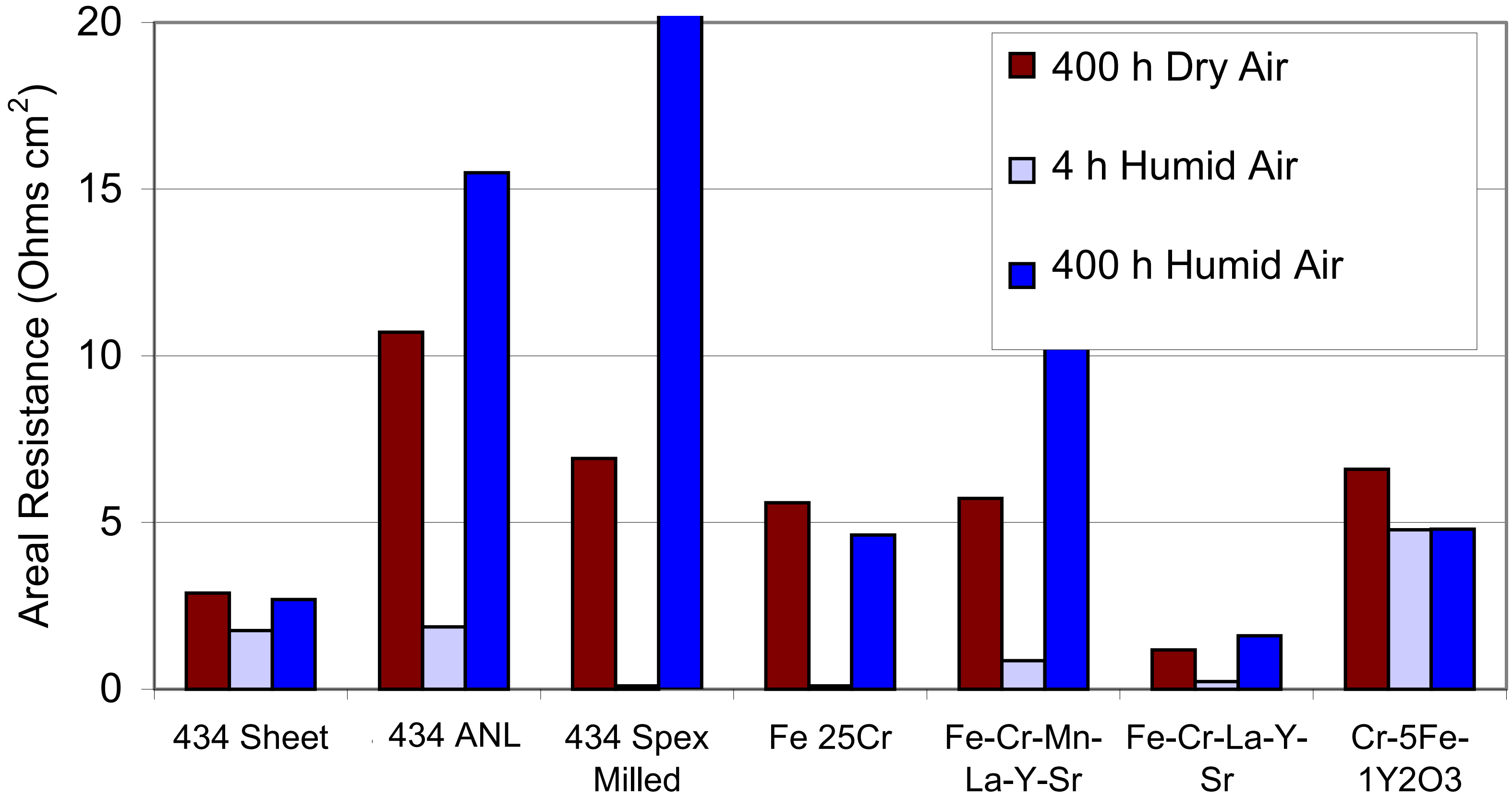
Metallic Interconnect Development
Approach

- Alloys similar to ferritic stainless steels
  - reduce Cr, other elements that can degrade fuel cell performance
  - additives to improve properties and protective scale
- Coated materials to impart chemical stability
- Powder production by mechanical alloying techniques
- Processing technique can yield almost any desired shape
  - flat, corrugated, textured, functionally graded



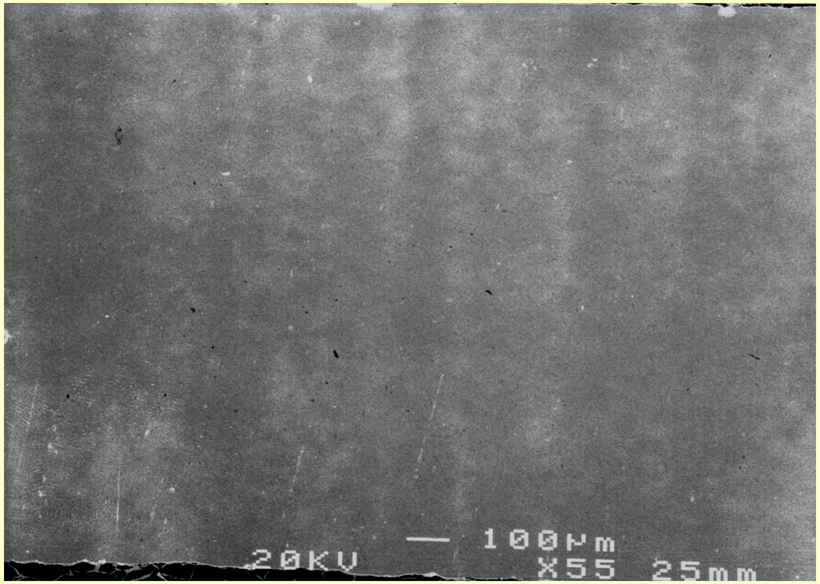
Metallic Interconnect Development

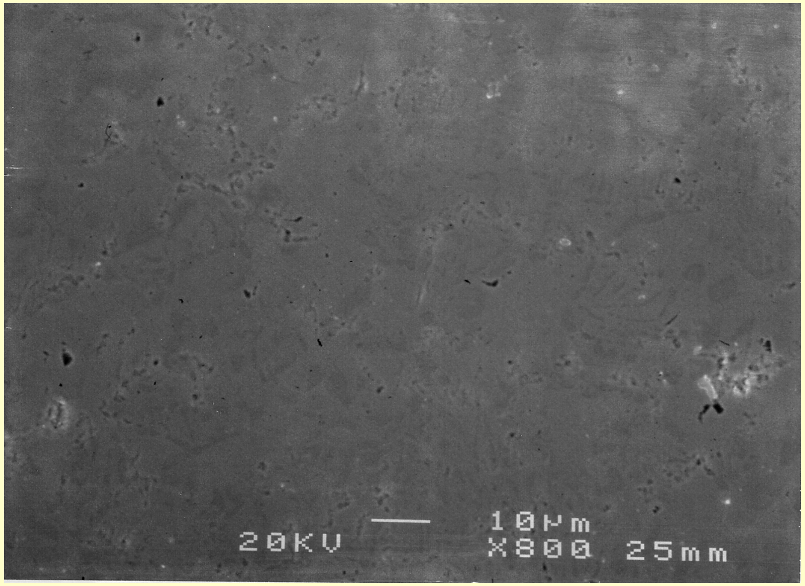
Electrical resistance of the oxide scale



Metallic Interconnect Development

Multi-layer plates show excellent bonding





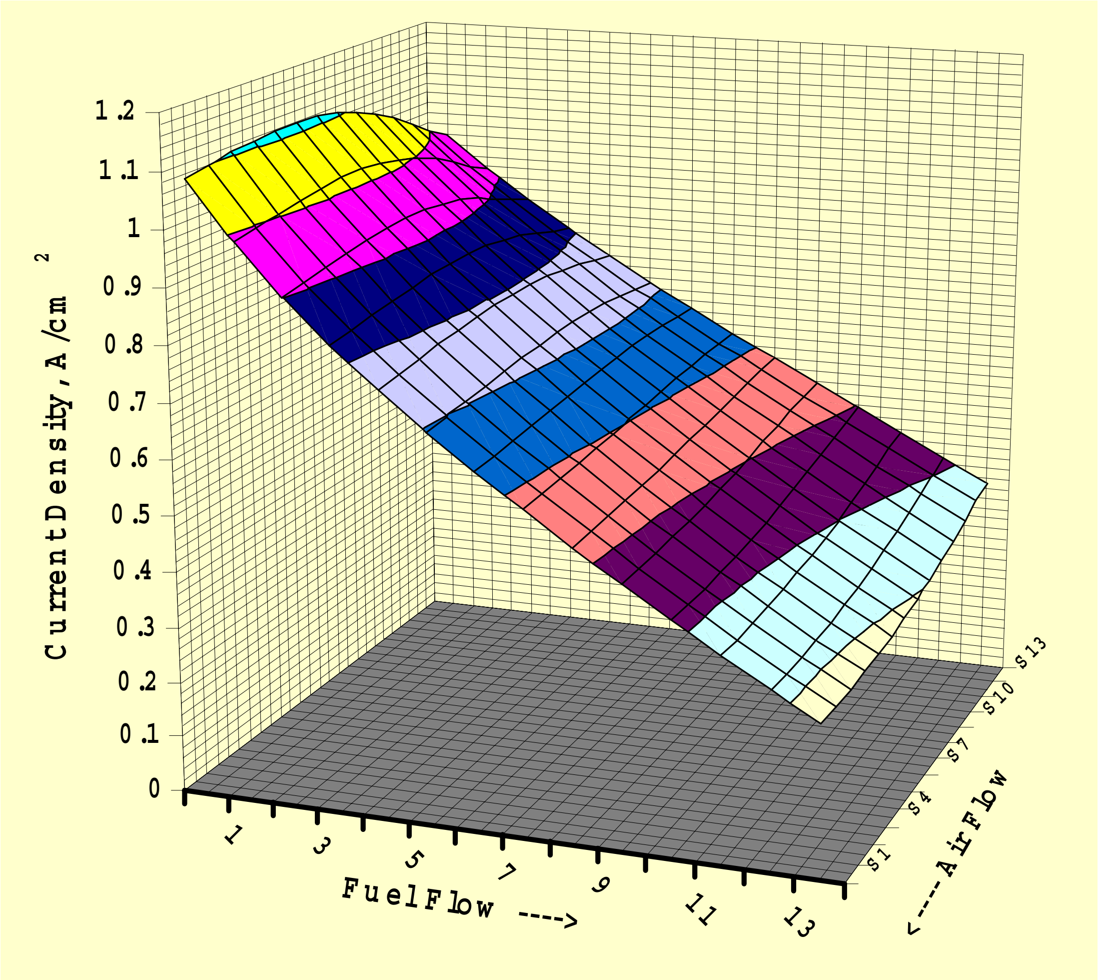
10 layers of ferritic stainless steel alloy

Each layer ~140 µm thick

(Fe-Cr-La-Y-Sr)

Cell, Stack, and Systems Modeling
Current density distribution, 0.7 V, 85% u_f

- Single cell model: sample results
- Current density can vary by a factor of 5



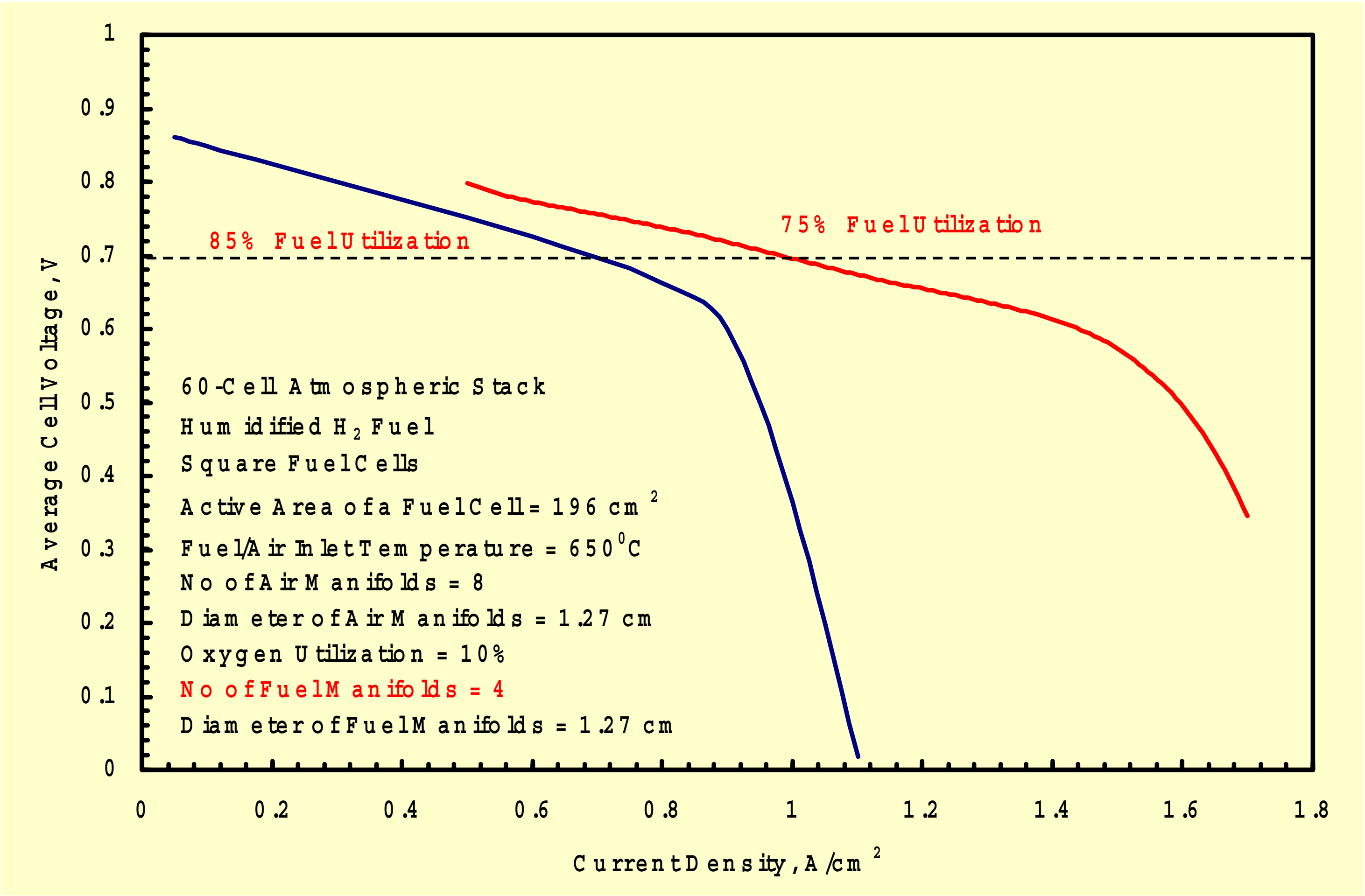
Cell, Stack, and Systems Modeling

Cell performance change with reformate

	Humidified H_2	Reformate
Active Cell Area	196 cm^2	196 cm^2
Fuel Composition	95.2% H_2	59.2% H_2
	4.8% H_2O	19.3% H_2O
		4.2% CH_4
		10.3% CO
		7.1% CO_2
Inlet Temperature	650 ^{0}C	650 ^{0}C
Max Cell Temperature	804 ^{0}C	800 ^{0}C
Fuel Utilization	85.30%	85.30%
Oxygen Utilization	7.30%	9.40%
Call Voltage	0.7 V	0.7 V
Avg Nernst Potential	0.86 V	0.84 V
Avg Current Density	0.65 A/cm^2	0.518 A/cm^2
Gross Power	89.4 W	71 W
Net Power	87.1 W	70.1 W

Cell, Stack, and Systems Modeling

Stack performance vs. fuel utilization



Summary
Current and future work

- 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, as appropriate