

Low-Temperature SOFC Materials Development at ANL

Michael Krumpelt
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Argonne National Laboratory

Presented at:

SECA Core Technology Review
June 18-19, 2002
Pittsburgh, PA

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*Work supported by the U.S. Department of Energy, Office of Advanced Automotive Technologies, Office of Transportation Technologies, under Contract W-31-109-ENG-38.



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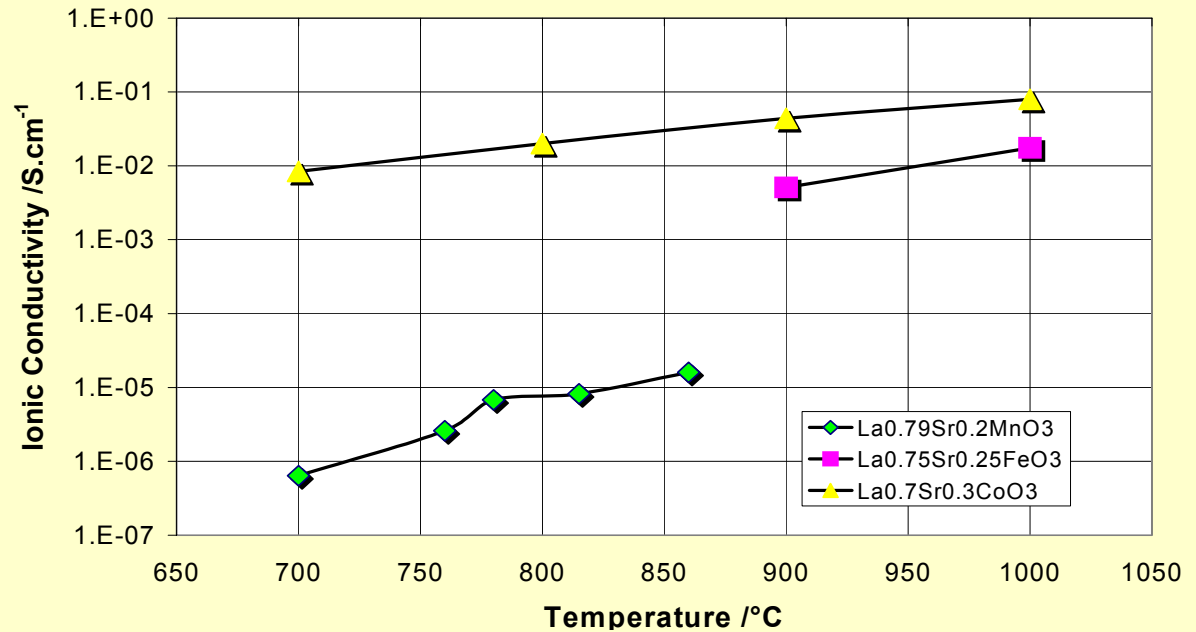


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Technical Issues

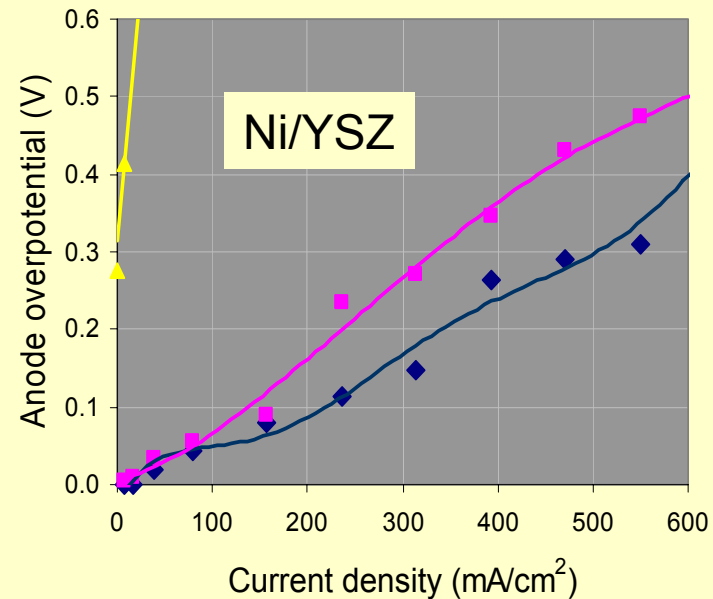
Cathodes:

Lanthanum manganite becomes a marginal cathode below 1000°



Anodes:

Reformed gasoline, diesel or propane contain higher levels of H_2S than natural gas



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Issues (continued)

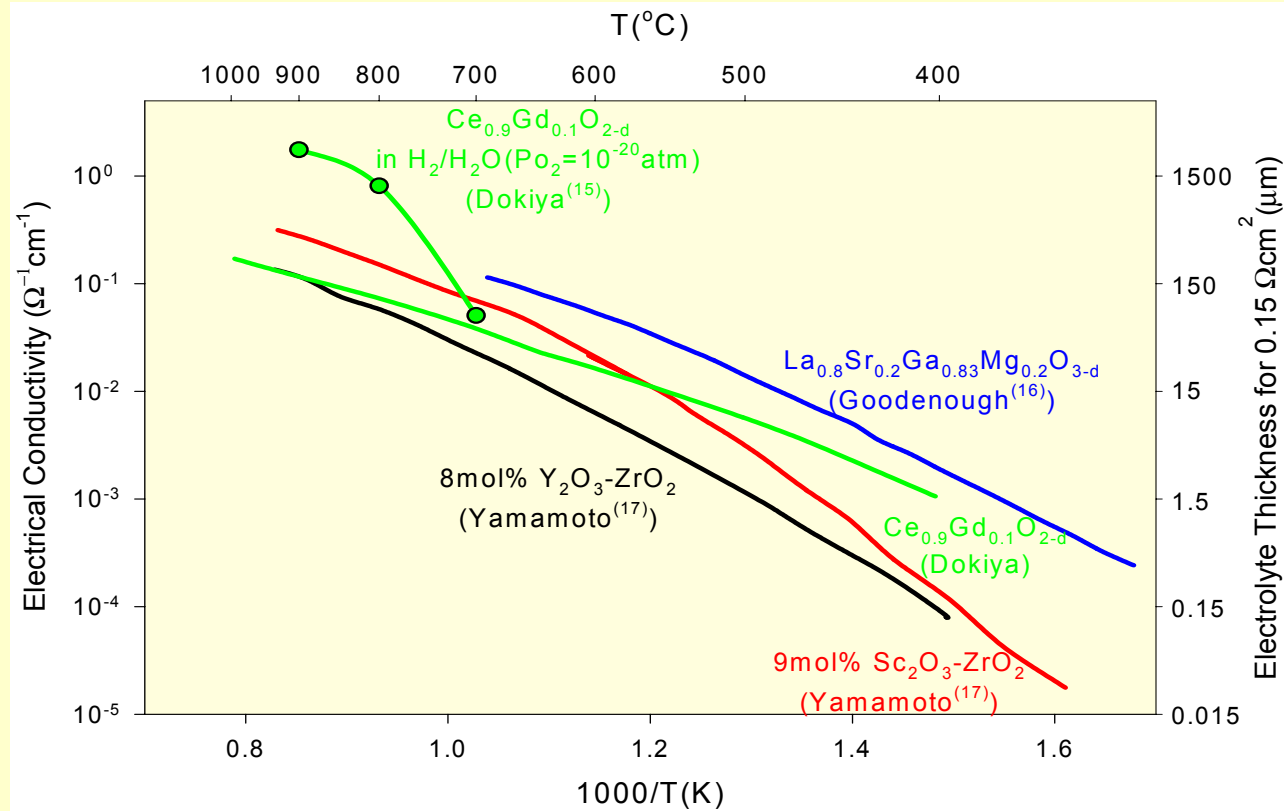
Bipolar Plate

Chromium volatilizes from stainless steels and poisons the electrode reactions

Type of Steel	Transpiration Rate $\mu\text{g m}^{-2}\text{s}^{-1}$
$\text{Cr}_5\text{Fe1Y}_2\text{O}_3$	132
$\text{Fe}_{20}\text{Cr}_5\text{Al}$	27
446	6

Electrolyte

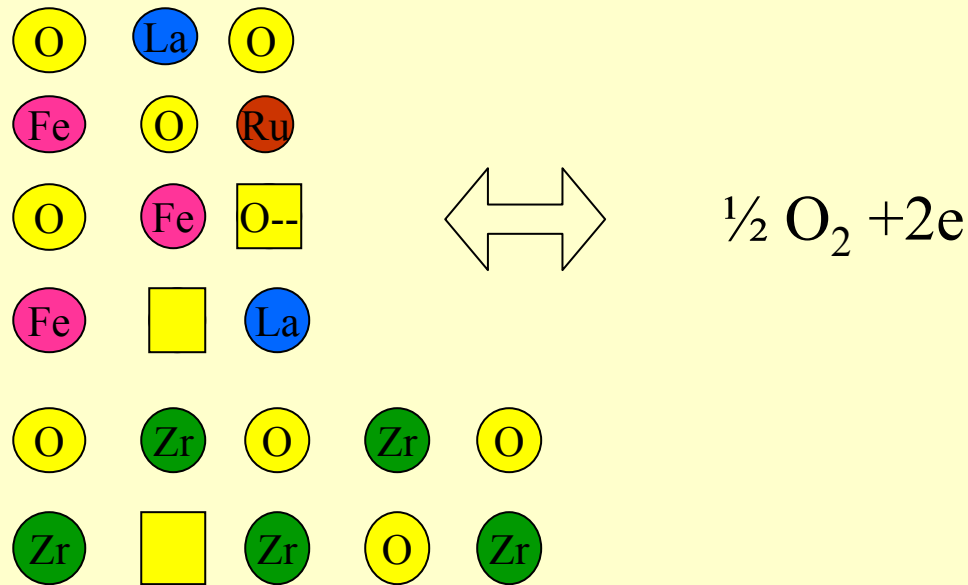
No issues



R & D Objectives and Approaches

Cathodes

- Synthesize and test materials with improved oxide ion conductivity
- Implant secondary ions into surface to enhance oxygen exchange coefficient



R&D Objectives and Approaches

Anodes

- Develop materials that are more sulfur tolerant than Ni/YSZ.
 - Explore new classes of materials such as WC.
 - Modify nickel surface with metals that have lower affinity for sulfur.

Metal	ΔG_2 (kJ/mol H ₂ S)
Ni	-160
Ru	-69
Pt	-66
Rh	-46
Ag	-38
Pd	+



R&D Objectives and Approaches

Bipolar Plate

- Prepare and test ferritic stainless steels with reduced chromium transportation rates.
- Prepare and test ferritic steels without chromium.
- Prepare and test additives to improve oxidation and electrical characteristics.
- Prepare and test best compositions as functionally graded materials.

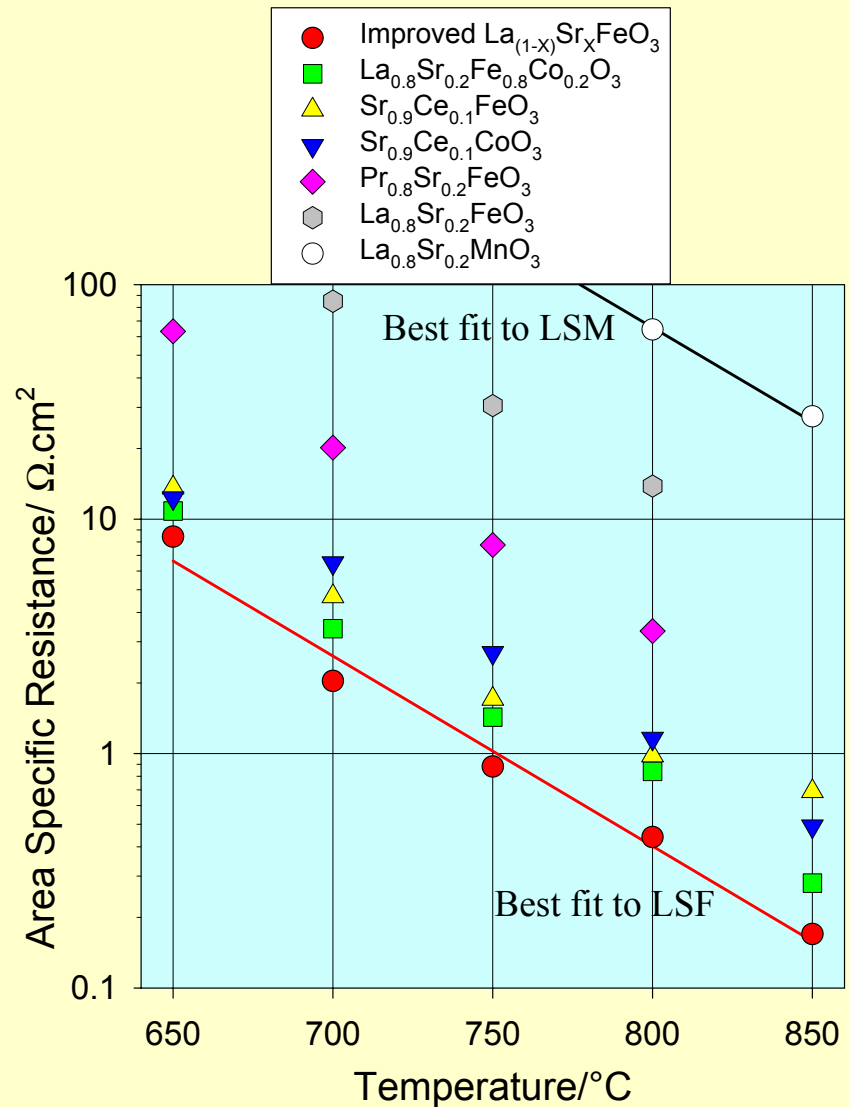


Results to Date - Cathodes

Ferrite-based perovskites significantly better than manganites

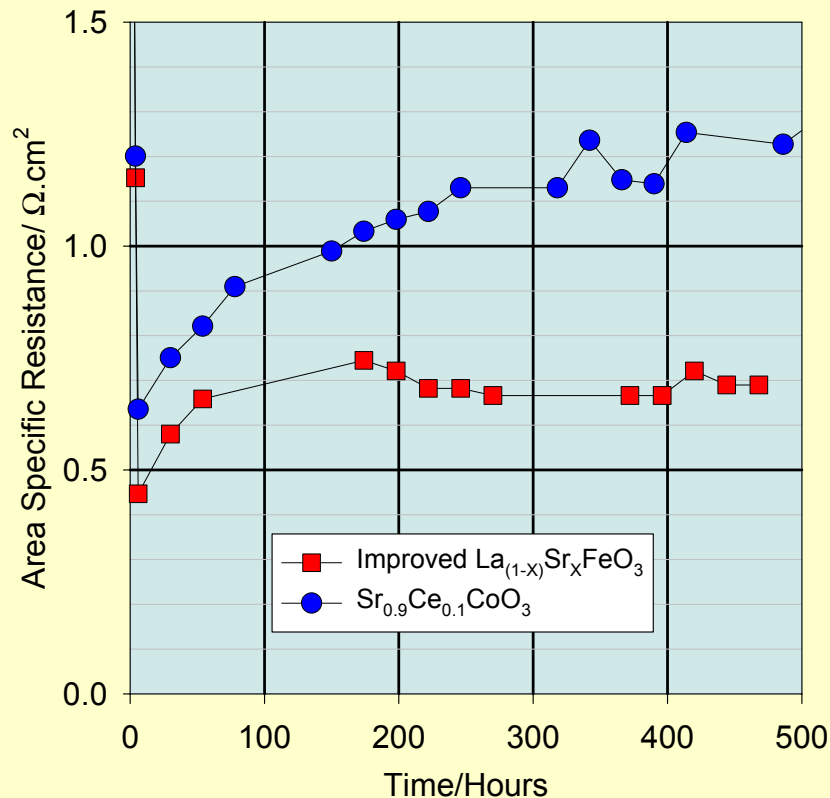
Best performances achieved when ferrite does not react with YSZ

Pr substitution for La appears beneficial – may be an active component (Pr^{3+} - Pr^{4+})

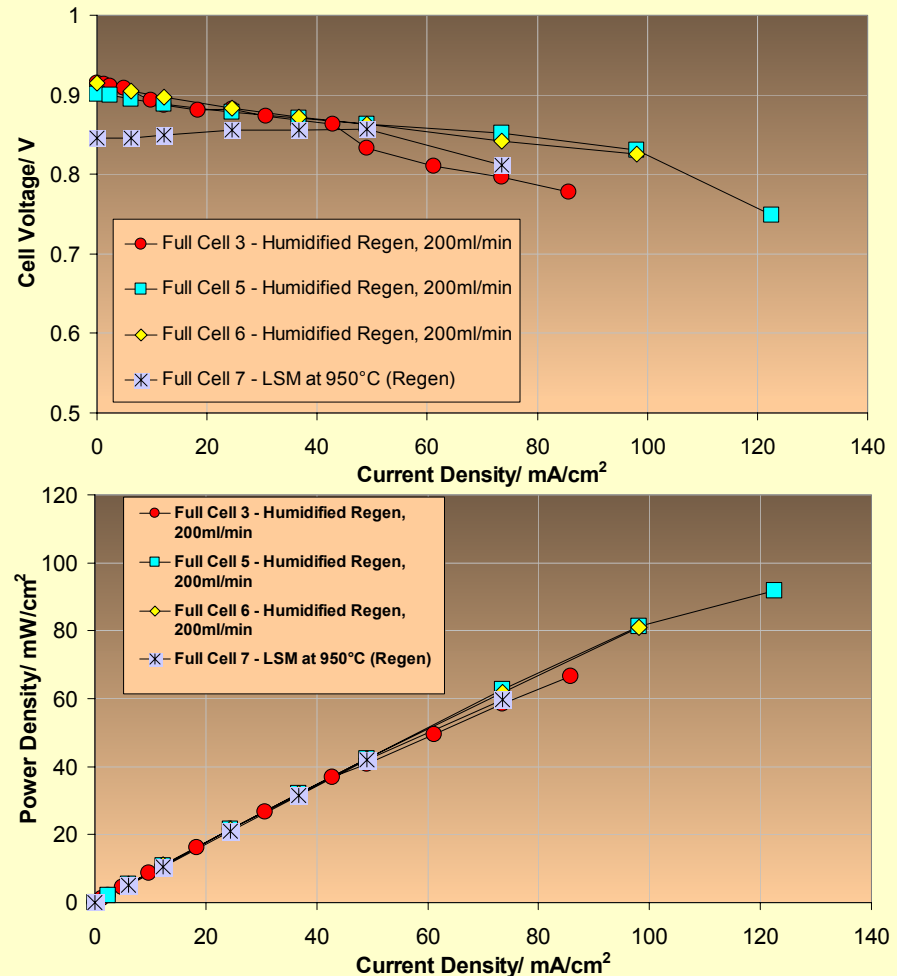


Results to Date - Cathodes

Long-term and full cell performance appears encouraging for improved $\text{La}_{(1-X)}\text{Sr}_X\text{FeO}_3$ and $\text{Sr}_{0.9}\text{Ce}_{0.1}\text{CoO}_3$



Full Cell Performance of $\text{La}_{(1-X)}\text{Sr}_X\text{FeO}_3$ at 800°C compared to LSM at 950°C



Results to Date - Anodes

- Built a fuel cell test stand with silica coated gas manifold and H₂S/reformate metering capability.
- Prepared half cells on YSZ discs with surface modified nickel.

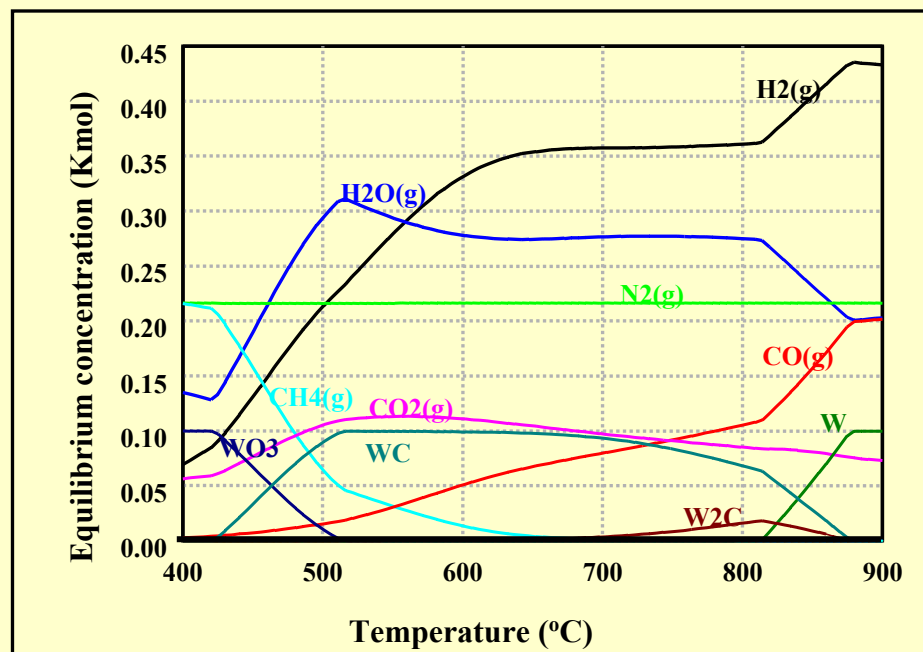


Results to Date: Anodes

WC Anodes were made by:

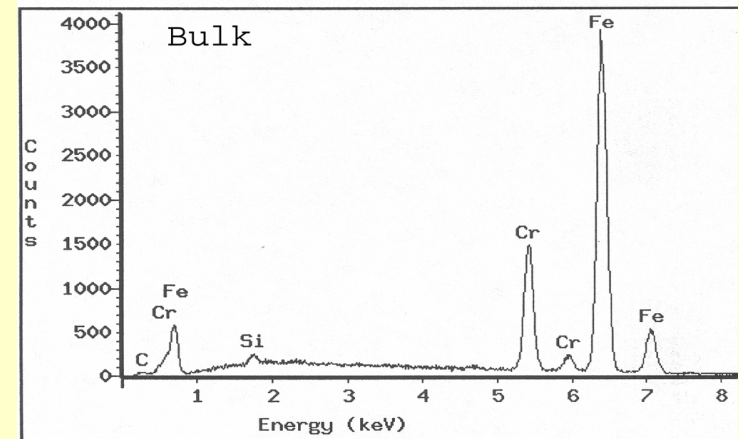
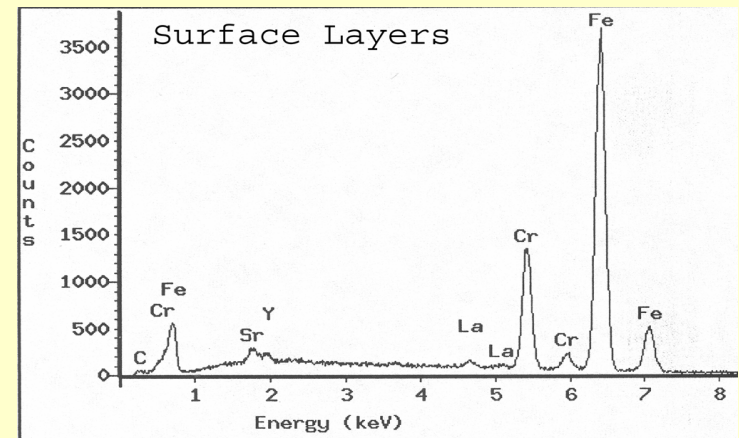
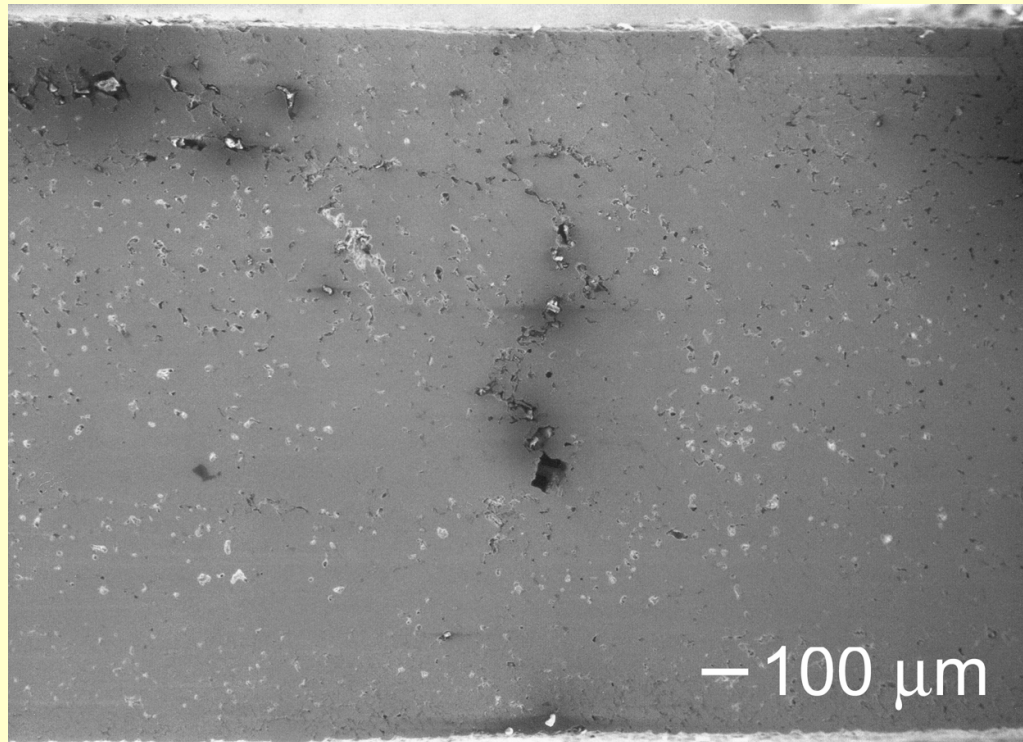
- sintering YSZ/WC in various gases
- reacting YSZ/ WO_2 with CH_4

Sintering Temperature	Initial Material	Constituents Formed	Sinterability
800°C	YSZ/ WO_3 (99.8)	W and WO_2	Poor
800°C	YSZ/ WO_3 (99.99)	W and WO_2	Poor
900°C	YSZ/ WO_3 (99.8)	W and WC (more W than 99.99)	Moderate
900°C	YSZ/ WO_3 (99.99)	W and WC	Moderate
1000°C	YSZ/ WO_3 (99.8)	W (small amount) and WC	Moderate
1000°C	YSZ/ WO_3 (99.99)	WC	Moderate
1100°C	YSZ/ WO_3 (99.8)	WC	Good
1100°C	YSZ/ WO_3 (99.99)	WC	Good



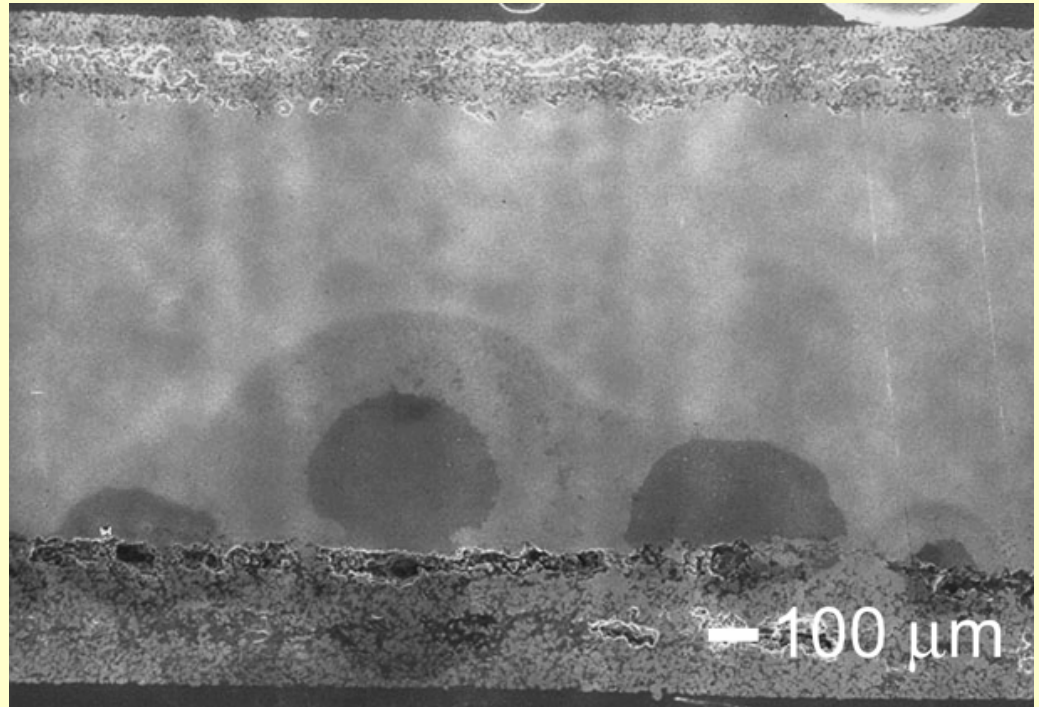
Results to date Bipolar Plate

- Alloys with modified surface compositions have been made



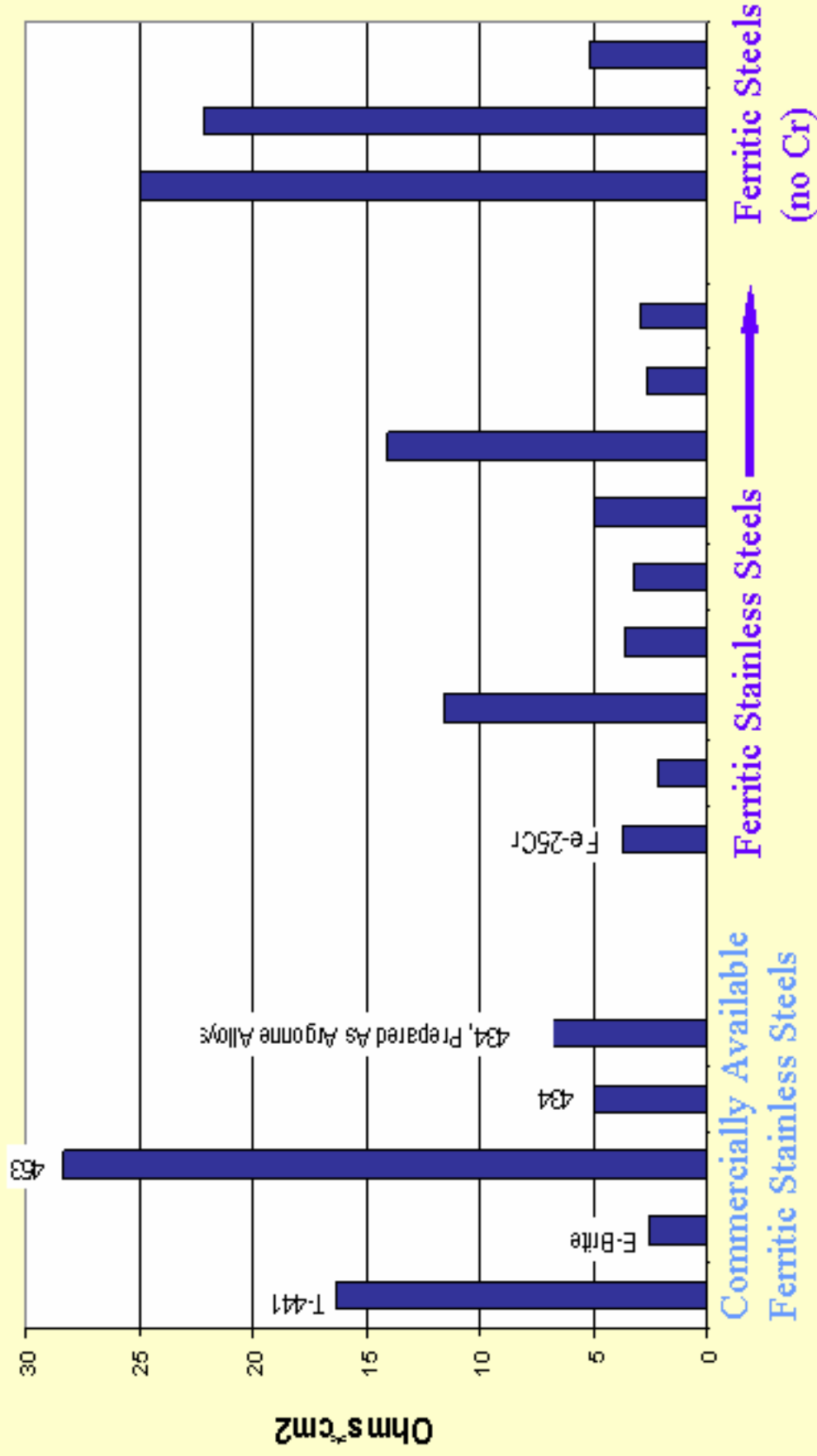
Results to date – Bipolar Plate

A compositionally
graded ferritic
stainless steel plate
with alloy/LaCrO₃
composite layers



Area Specific Resistance of Alloys

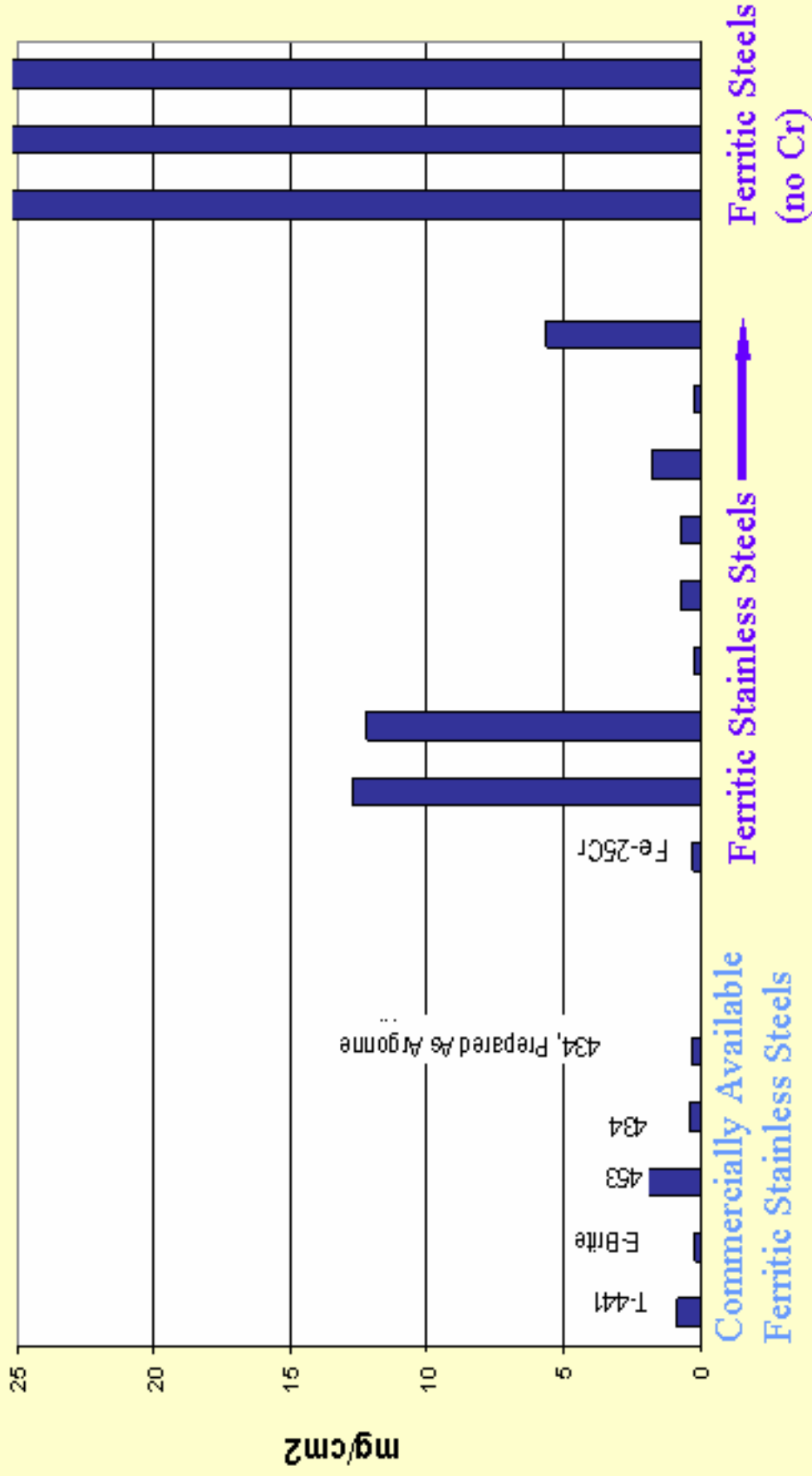
(At 800°C, 400 hrs Exposure Humid Air)



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Weight Gain of Alloys

(At 800°C, 400 hrs Exposure Humid Air)



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Applicability to SOFC Commercialization

- LSF cathodes still need microstructural optimization and life testing.
- Sulfur-tolerant anodes are not yet available.
- 5 x 5 cm test samples of experimental new bipolar plates will be available in the next 12 months for evaluation by others.



Activities for the Next 6-12 Months

Cathodes

- Focus efforts to optimize composition of best cathodes.
- Determine optimum microstructure and fabrication procedure for further improvement.
- Prove results in single cell and small stack tests.

Anodes

- Test experimental new anodes in H₂S containing fuel.

Bipolar Plates

- Make modifications to alloy compositions, produce, and test new alloys based on information from current materials' test.
- Scale-up process to 5 x 5 cm.

