LBNL Activity Overview

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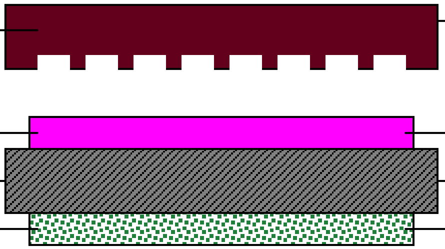
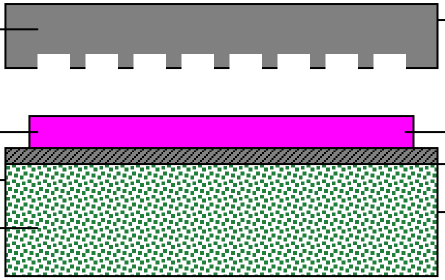
Presentation Outline

- Motivation for metal supported cell design
- Co-fired metal supported design
- Limitations of co-firing FeCr/NiO-YSZ/YSZ cells
- Cathode supported co-fired cell designs
- Single-step firing of thin-film SOFCs
- Potential benefit of using higher conductivity electrolytes
- Do thin-film LSGM cells make sense?
- Metal supported cells fabricated by post-fired bonding

Cost of SOFC Components



Component	Materials Cost	Fabrication
2 mm $LaCrO_3$	$40/kW	***Prohibitive*** $$$
50 µm LSM/YSZ	$6/kW	Screen-printing
200 µm YSZ	$24/kW	Tape-casting
50 µm Ni/YSZ	$6/kW	Screen-printing
	$76/kW	



Component	Materials Cost	Fabrication
0.25 mm Stainless	$3/kW	Sheet metal
50 µm LSM/YSZ	$6/kW	Screen-printing
10 µm YSZ	$1/kW	Screen-printing
2 mm Ni/YSZ	**$150/kW**	Tape-casting
	$160/kW	

SECA Target $400/kW System, then stack target $140/kW
So stack raw materials must be less than $85/kW

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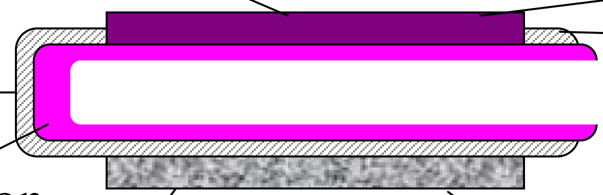
Cost of SOFC Components

Component **Materials Cost** **Fabrication**

LaCrO$_3$ by plasma spray

YSZ by EVD

LSM by extrusion



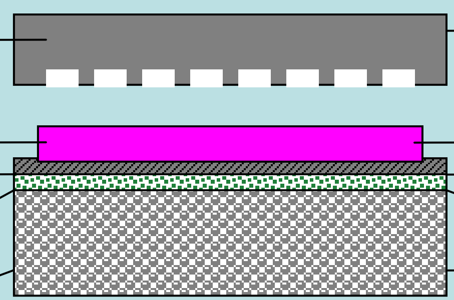
Nickel felt

Prohibitive

COA OK

Expensive

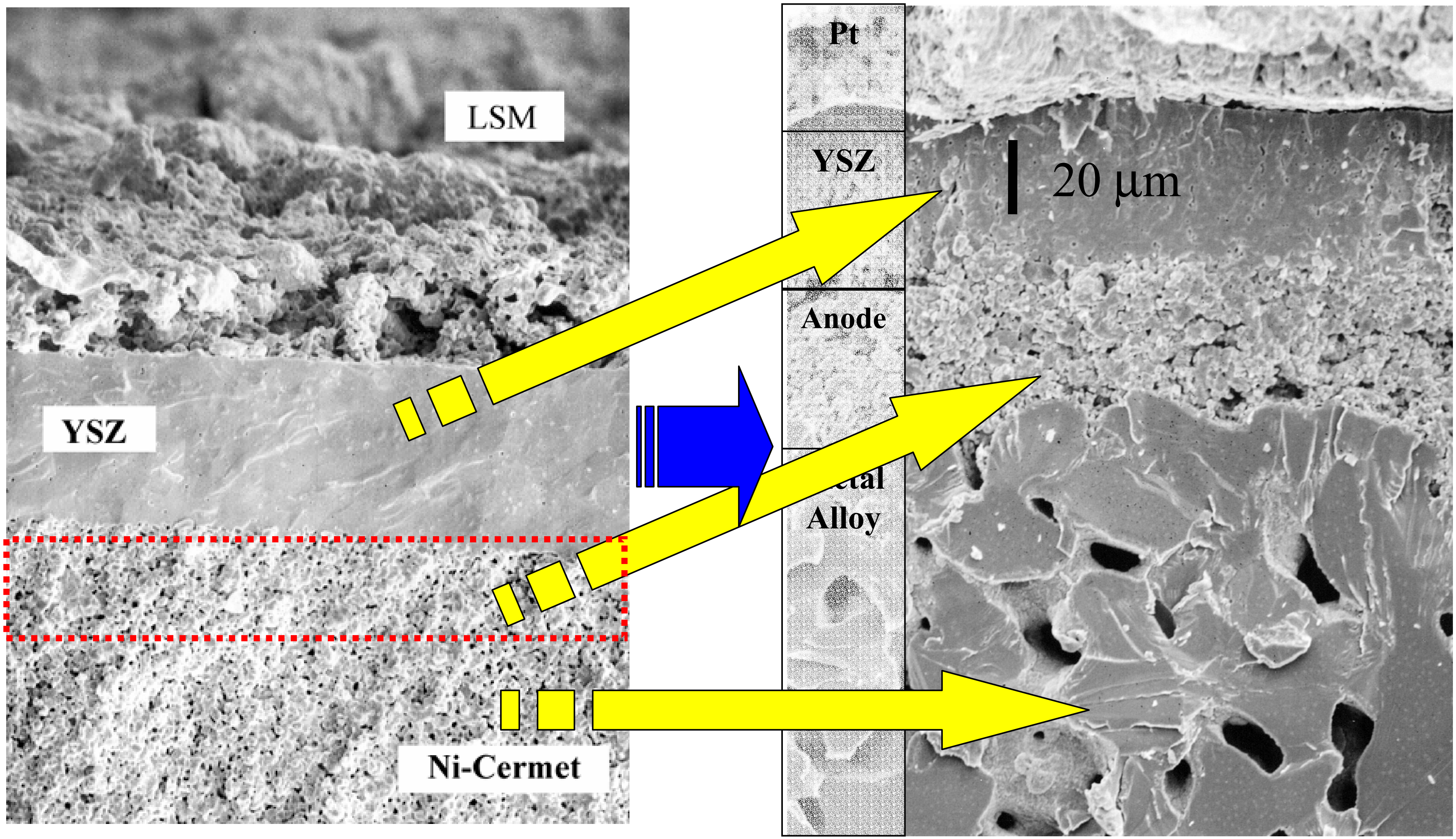
CVD-EVD is prohibitive



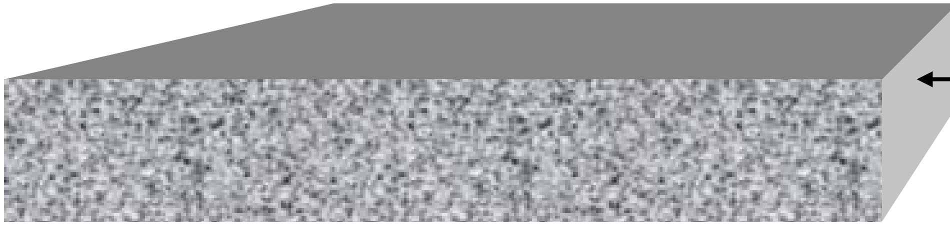
Component	Materials Cost	Fabrication
0.25 mm Stainless	\$3/kW	Sheet metal
50 µm LSM/YSZ	\$6/kW	Screen-printing
10 µm YSZ	\$1/kW	Screen-printing
10 µm Ni/YSZ	\$1/kW	Screen-printing
2 mm Stainless	\$26/kW	Tape-casting
	\$37/kW	

For tubular replace interconnect with S.S. mesh + \$7/kW

Development of Metal Supported Celll



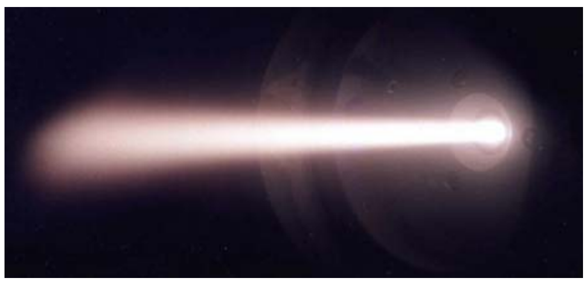
Fabrication Issues

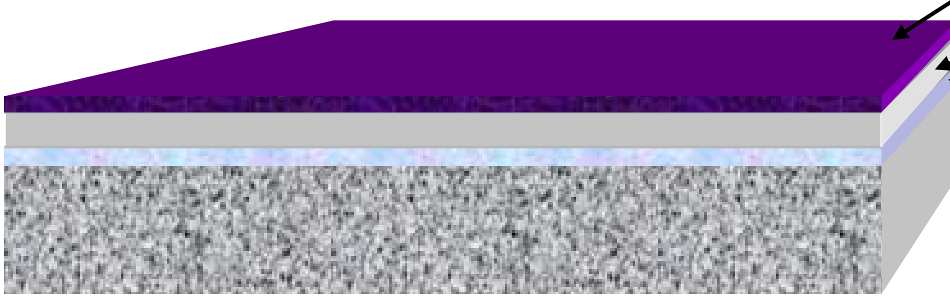


Porous high strength commercial alloy or metal-ceramic support (1 - 2 mm)

VPS onto steel substrate

Plasma torch





Deposit cathode

YSZ electrolyte (40 - 80 μm)

Ni-YSZ electrode (10 - 20 μm)

Plasma-spray operating costs ~ $400/hr - it takes about 1 hour for 1 kW or $400/kw

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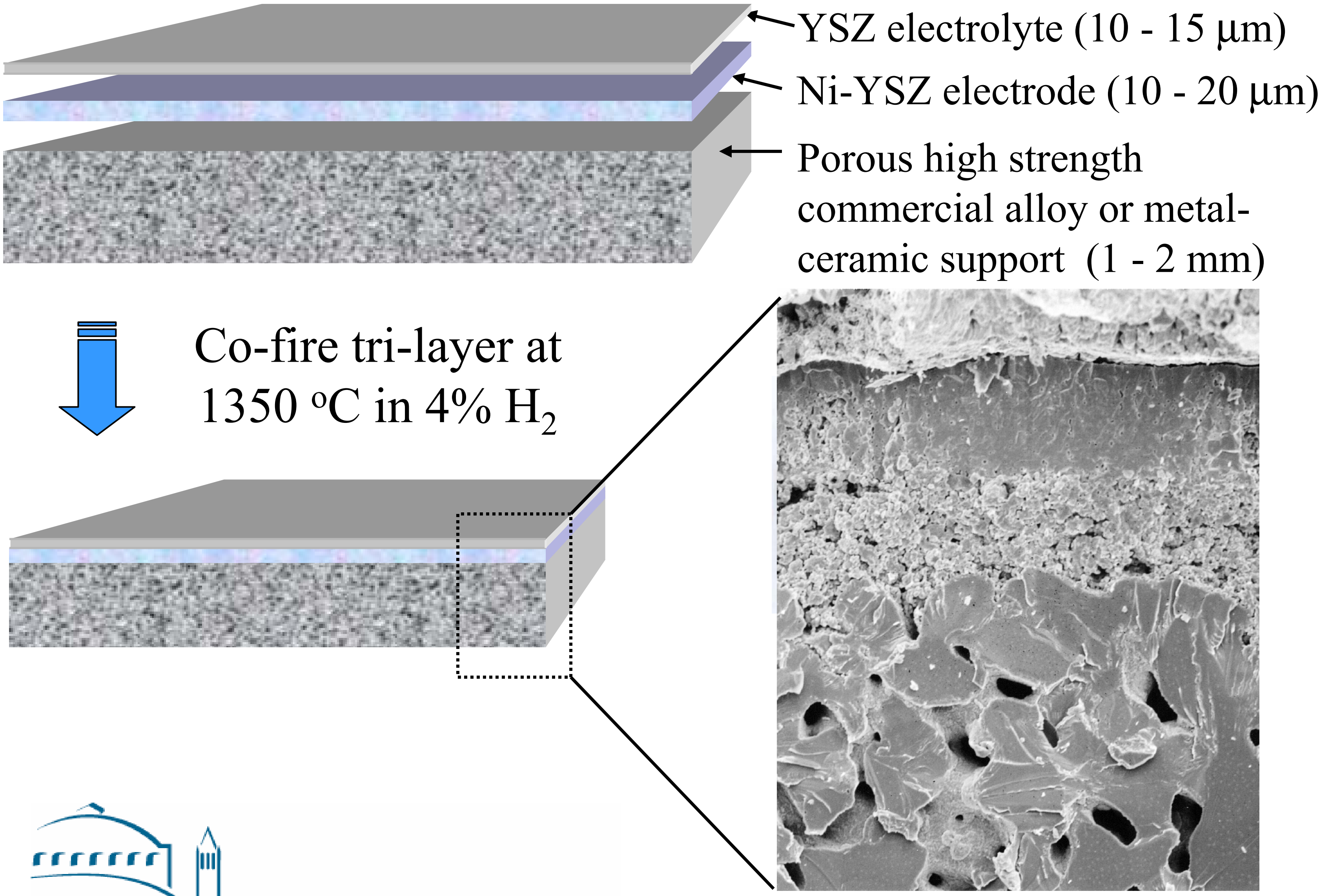
Fabrication of Low-Cost Planar SOFC



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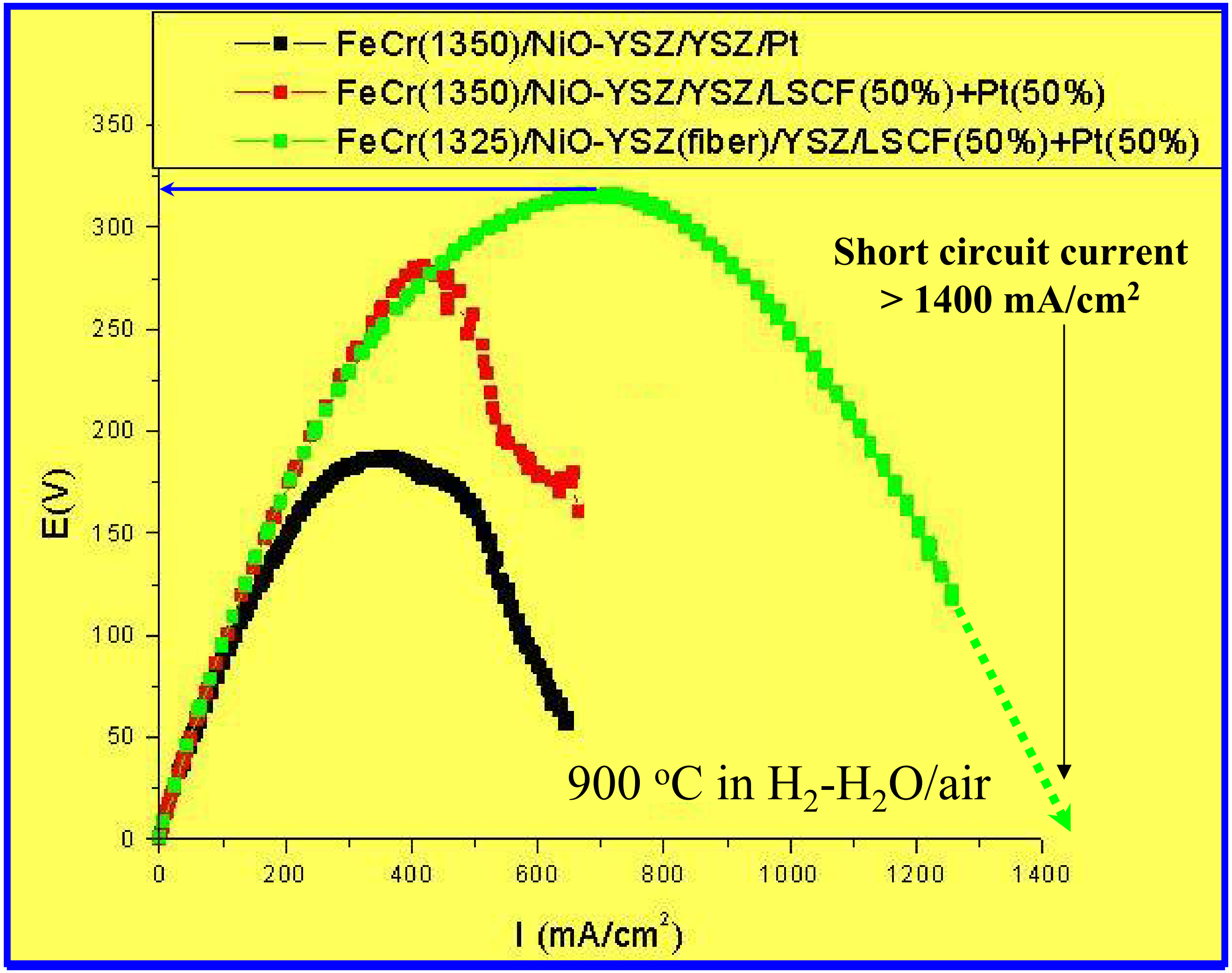
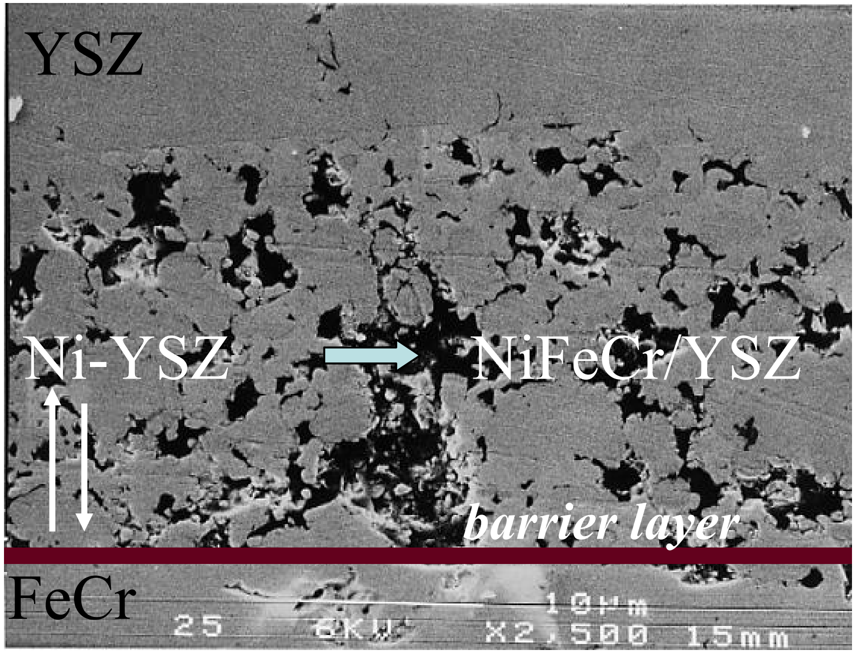
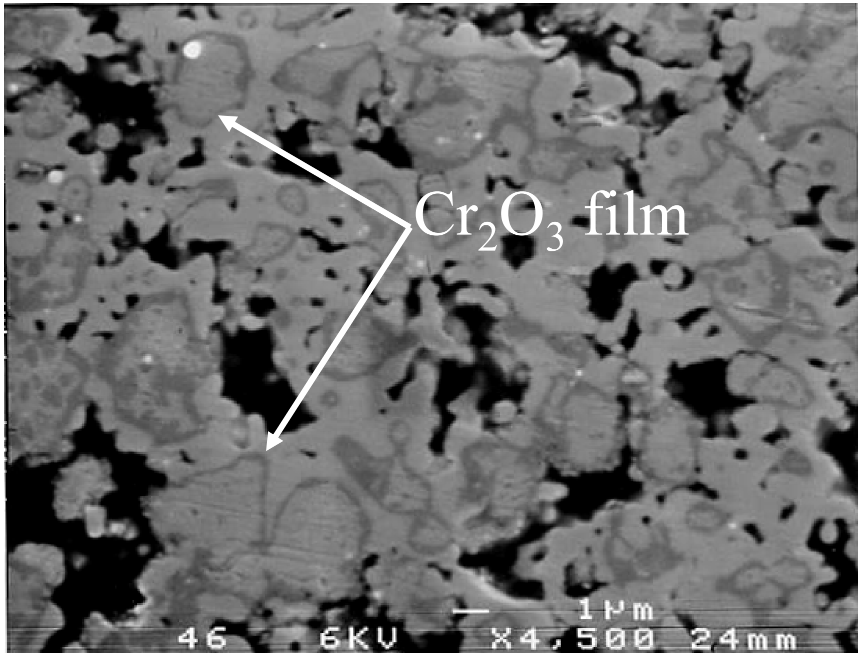
Performance of FeCr Supported Cell



Effect of FeCrNi on Anode Performance



After co-firing in 4% H_2 at 1350 ^oC



After testing in H_2-H_2O/air at 800 ^oC

Interdiffusion might be solved through the use of thin barrier layer ($LaCrO_3$), infiltration of Ni after co-firing and/or use of ceramic MIEC anode

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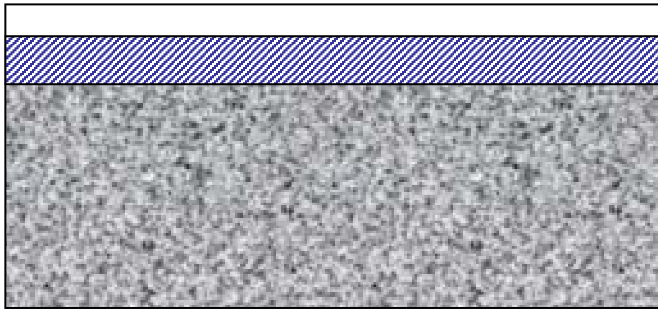
Use of MIEC Interlayer in Metal SOFC

YSZ



MIEC (i.e. $LaSrTiO_3$)

Co-firing to densify YSZ film > 1200 ^{o}C

FeCr

anode supported design

Many perovskites react with YSZ at co-firing temperatures

Sulfur tolerant anode

MIEC fired at low temp.

YSZ

LSM

cathode supported design

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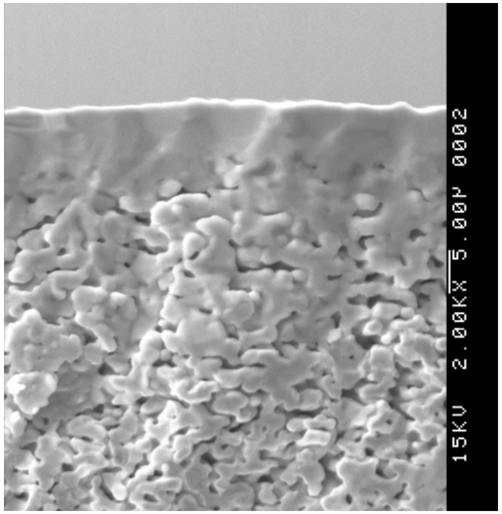
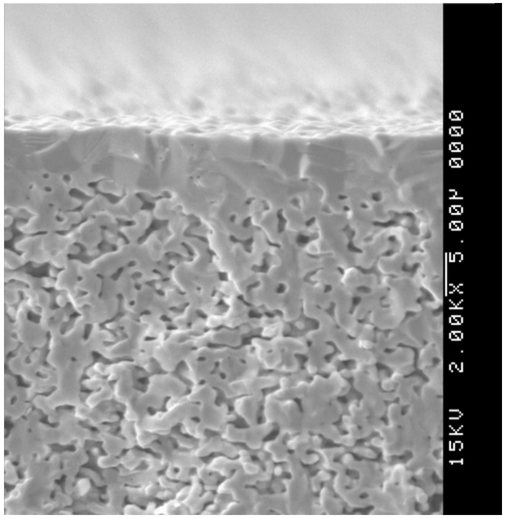
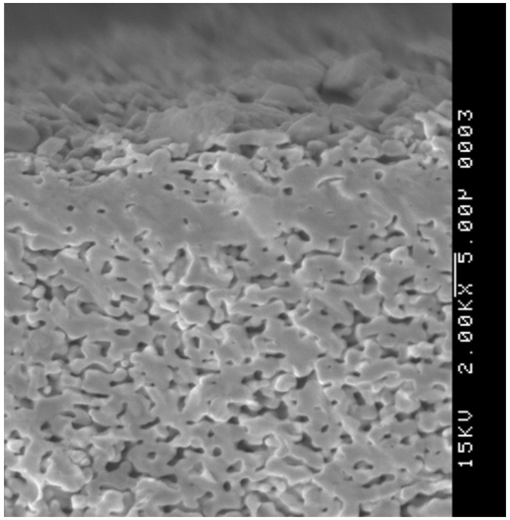
Cathode Supported Cells



YSZ on LSM

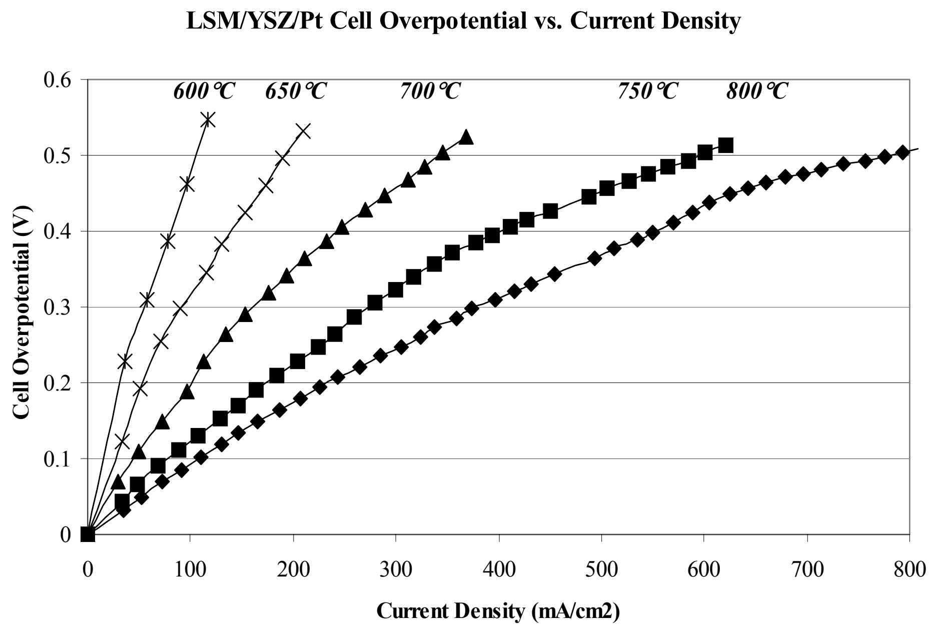


SSZ on LSM



LSGM on LSM

Performance of LSM/YSZ co-fired substrate with Pt anode operating as oxygen pump



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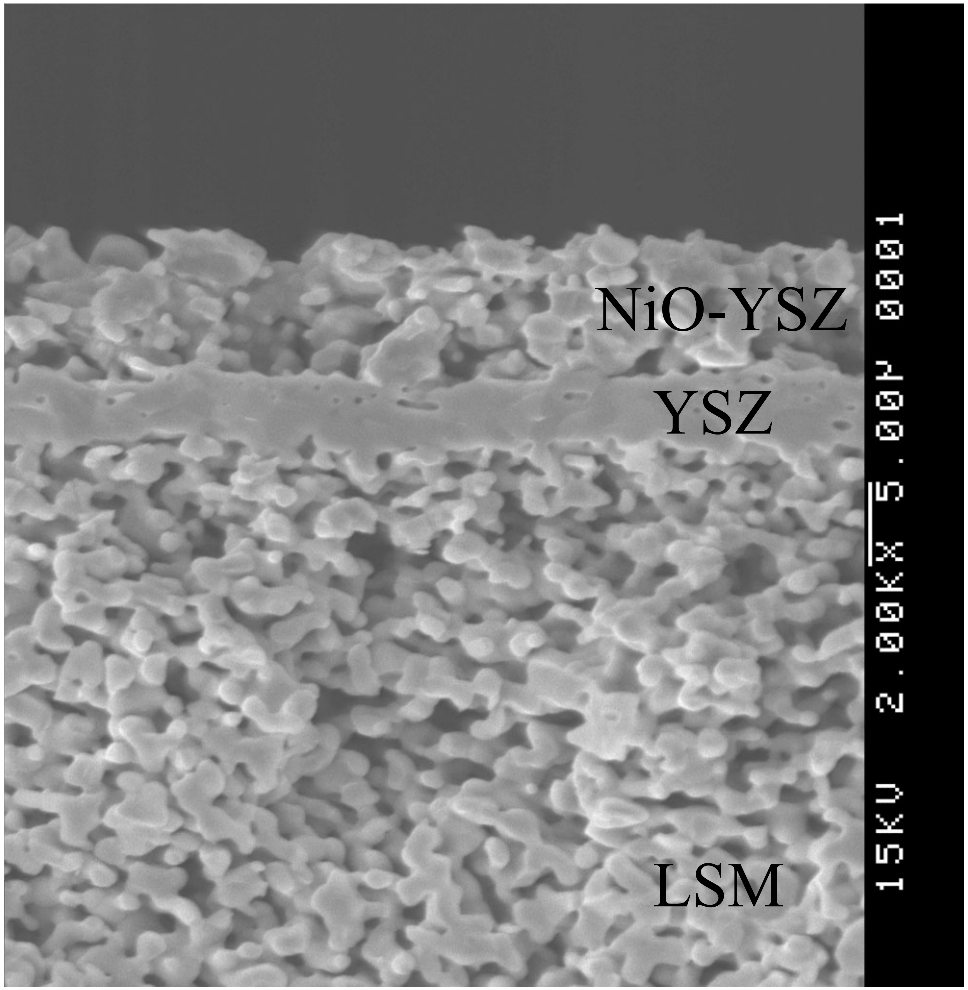
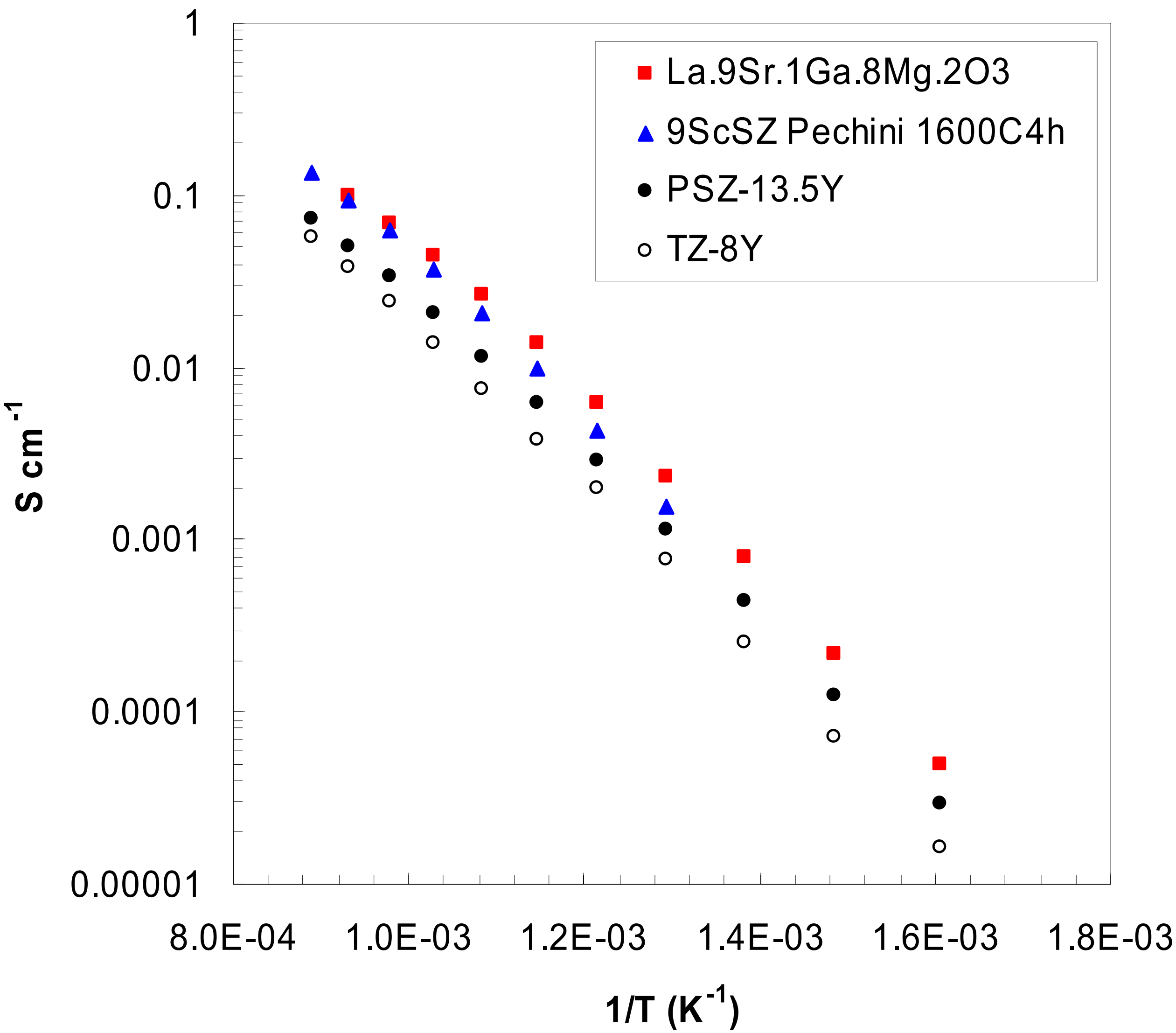
Single-Step Firing of SOFC

LSM/YSZ/NiO-YSZ tri-layered structure

co-fired at 1250°C for 4 hrs in air

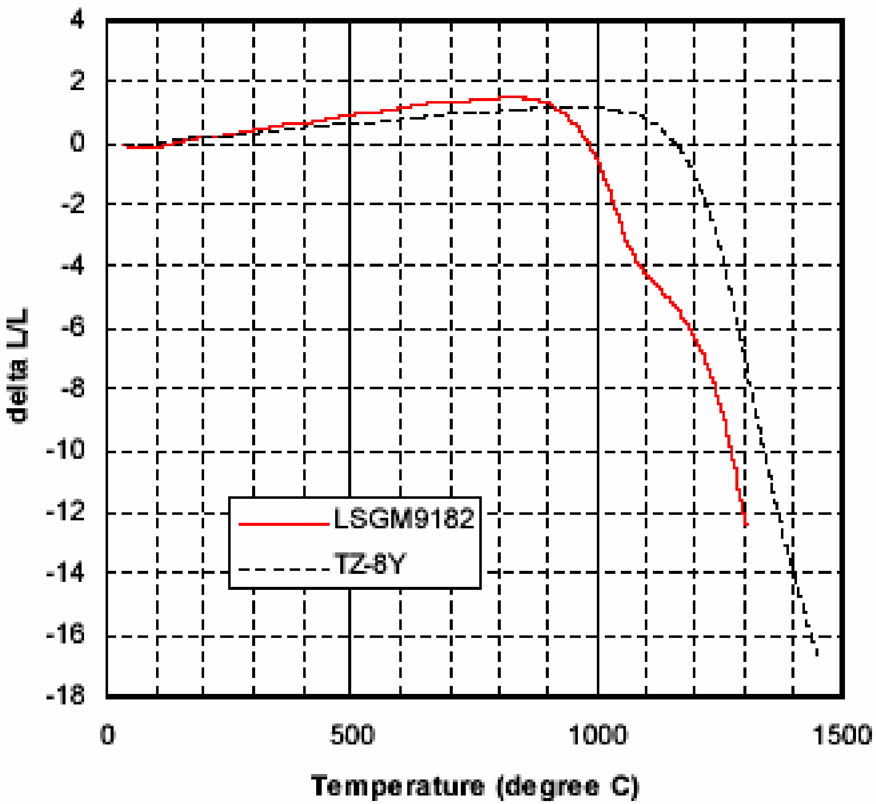


Conductivity of LSGM, SSZ, & YSZ

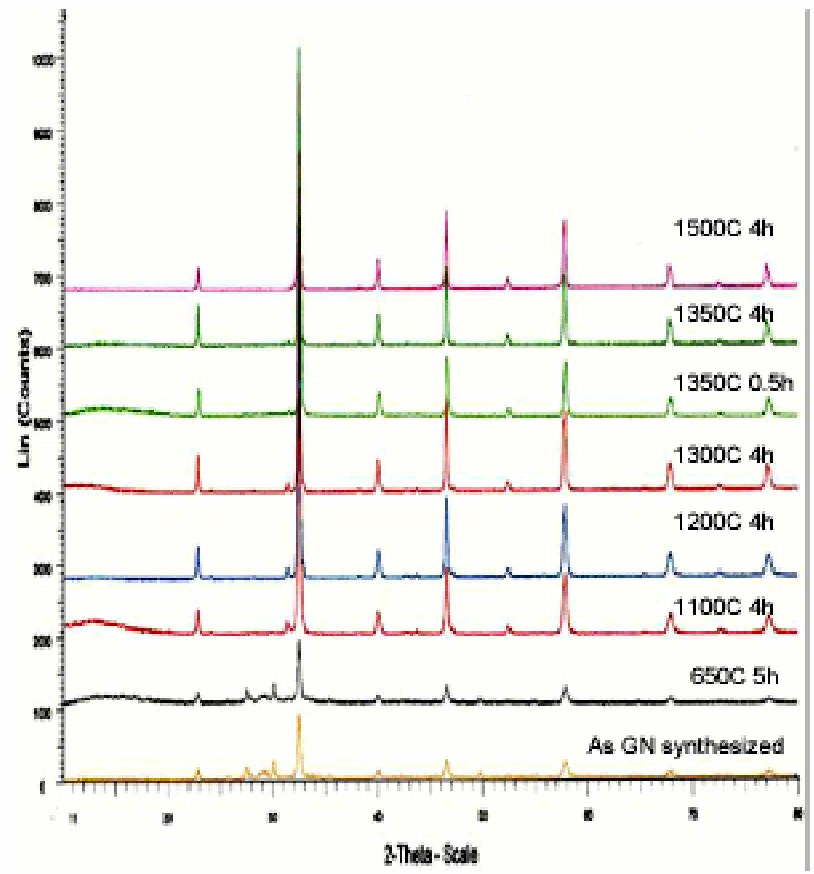


1/T (K^{-1})

Dilatometry & Xray Data



Sintering starts around 900C



Densities were 5.6 and 5.3 g/cm3 after sintering at 1400 and 1500˚C, respectively (95 and 90 % of theoretical density=5.874)

The perovskite structure was obtained at 1100˚C and above with an unknown small peak (2 θ=31.5) in the XRD patterns.

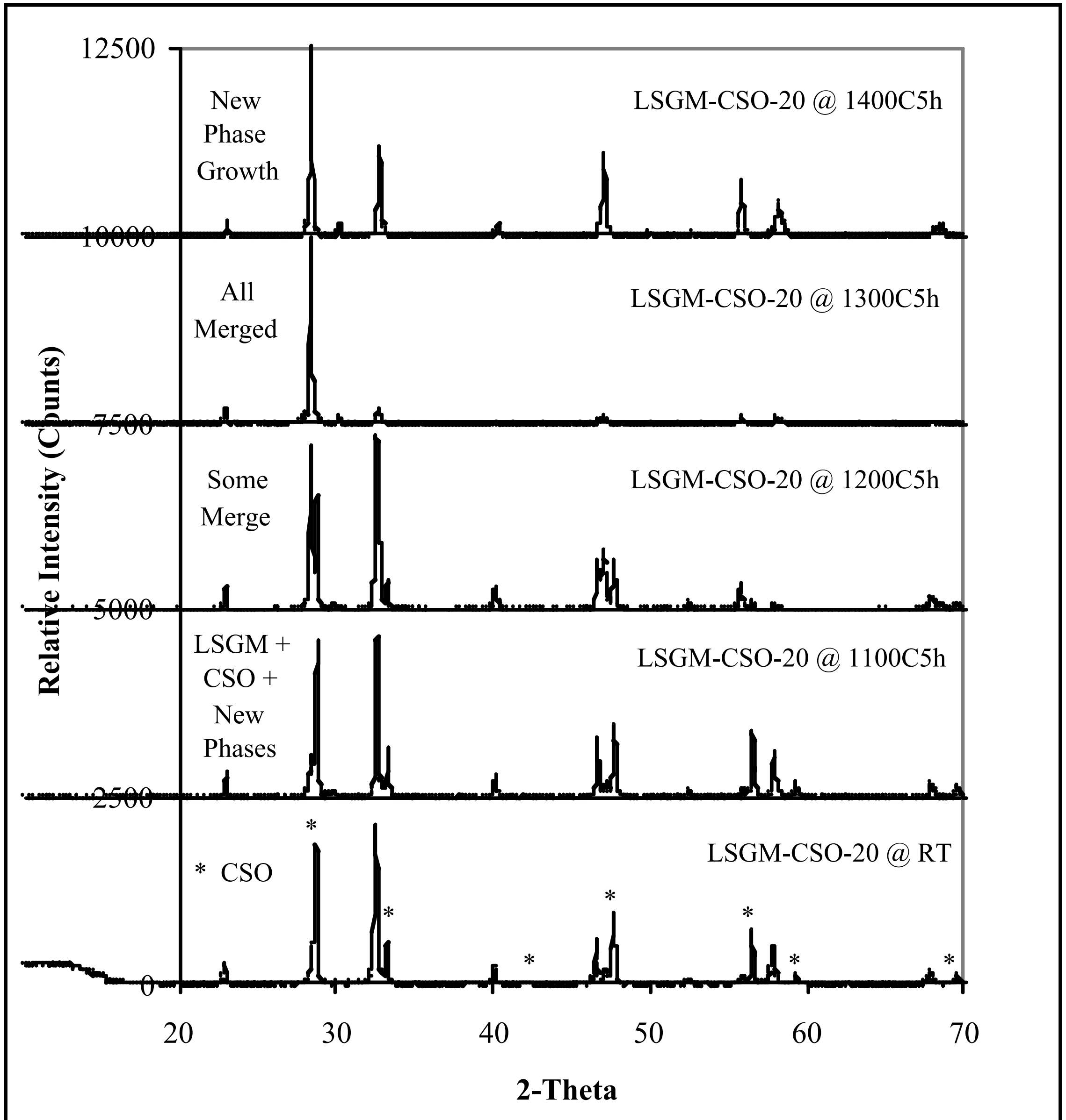
High Performance SOFCs with LSGM electrolytes

NiO-YSZ /LSGM (15 micron)/LSM, **0.85W/cm²** at 800C
Yan JW et al. J. Electrochmical Soc., 149(9), A1132(2002)

Ni-SDC /LSGMC (100 micron)/ $SmSrCoO_3$, **1.8W/cm²** at 800C
T. Inagaki et al.(Kansai Elecric Power), 2002 Fuel cell seminar abstract, p.423

Ni-SDC /LSGM (130 micron)/ $LaSrCoO_3$, **0.7W/cm²** at 800C
T. Fukui et al. (JFCC), J. Power Sources106,142 (2002)

High Performance Anode Supported Cell?



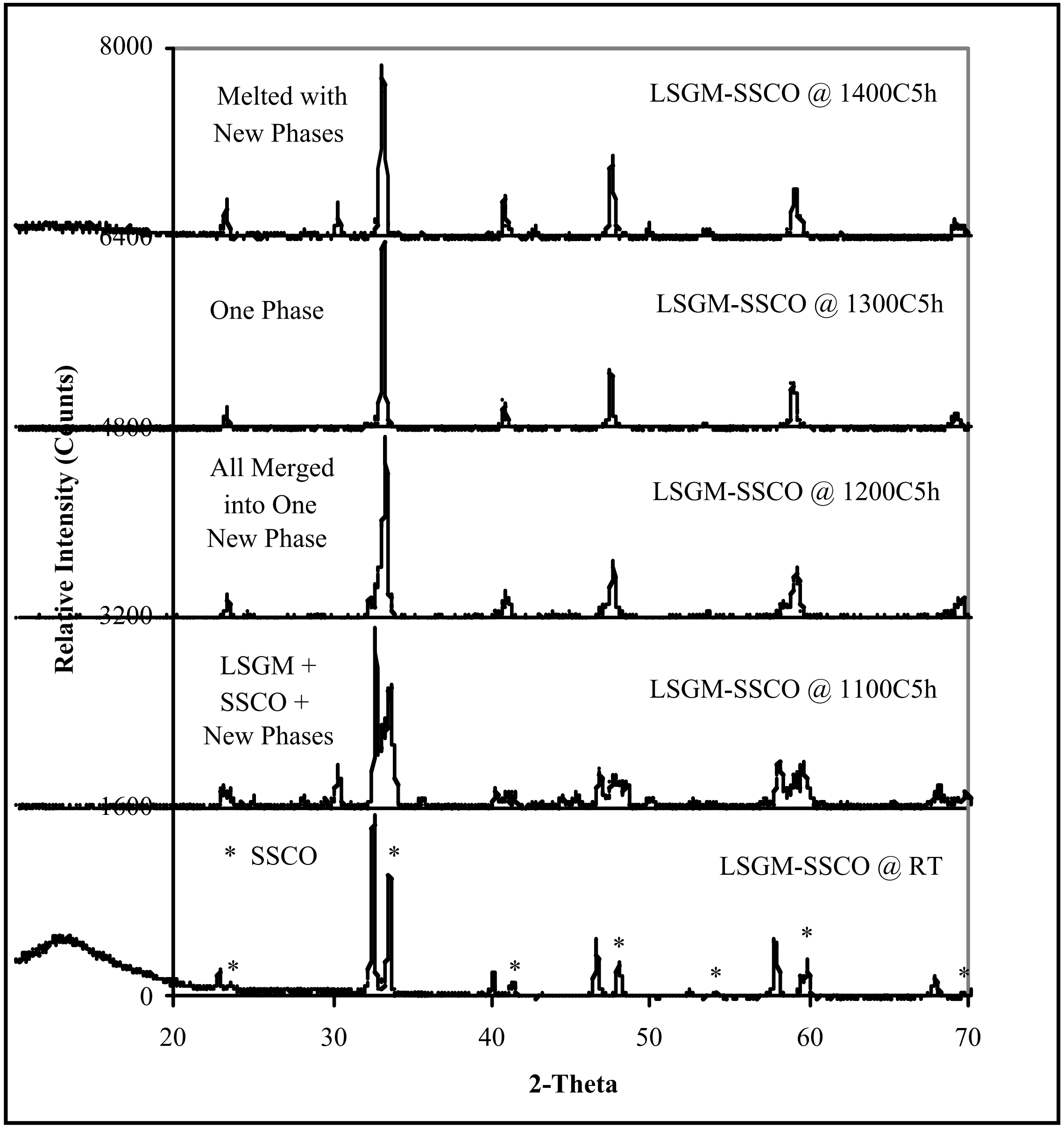
Anode Supported Cell

Infiltrate w/Ni

LSGM-CSO reaction couples at different temperatures

$(CeO_2)_{0.8}(SmO_{1.5})_{0.2}$
$La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{2.85}$

SSCO-LSGM Supported Cell



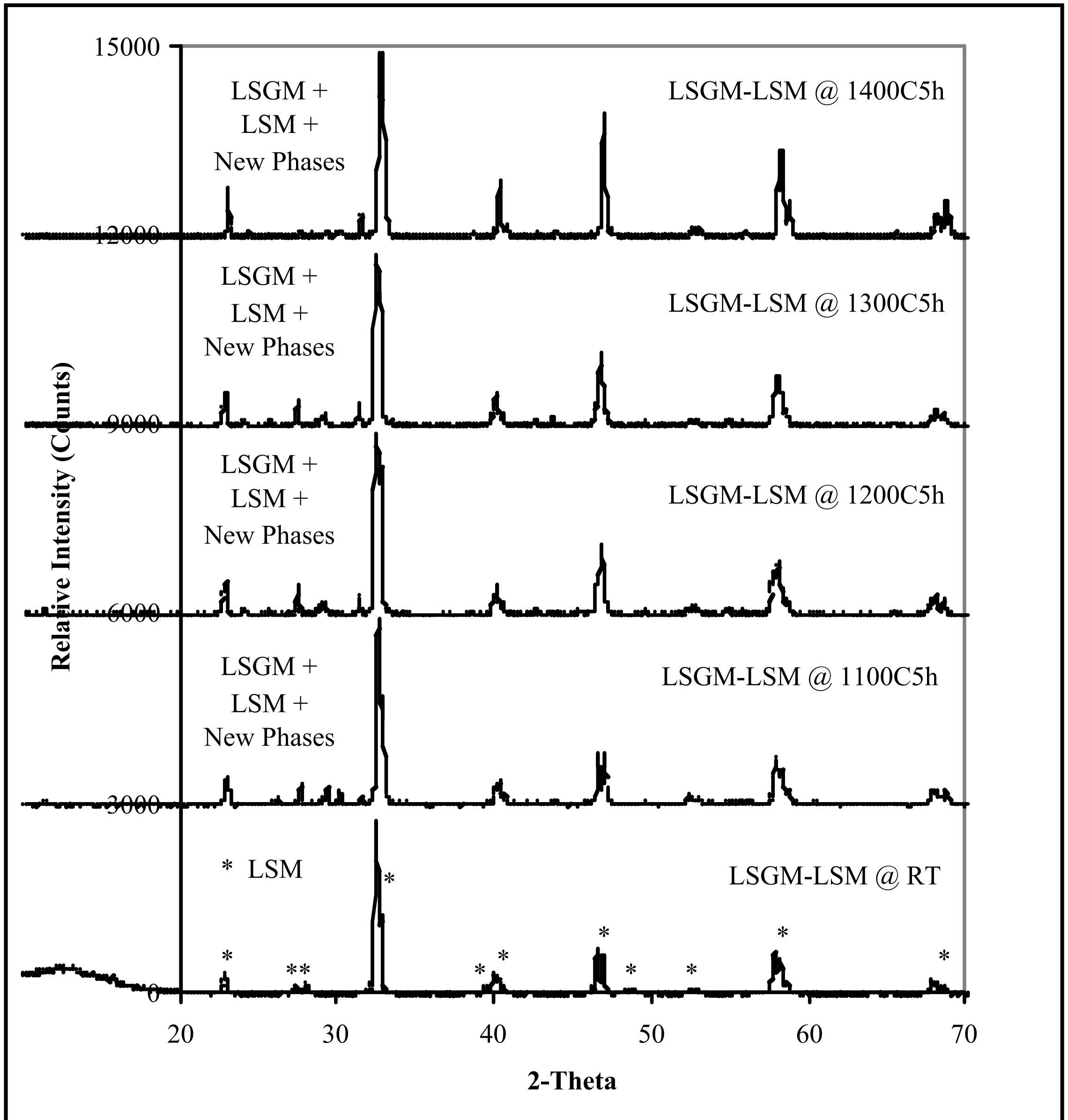
Cathode Supported Cell

LSGM-SSCO reaction couples at different temperatures.

$Sm_{0.5}Sr_{0.5}CoO_3$

$La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{2.85}$

LSM-LSGM Supported Cell



Cathode Supported Cell

LSGM

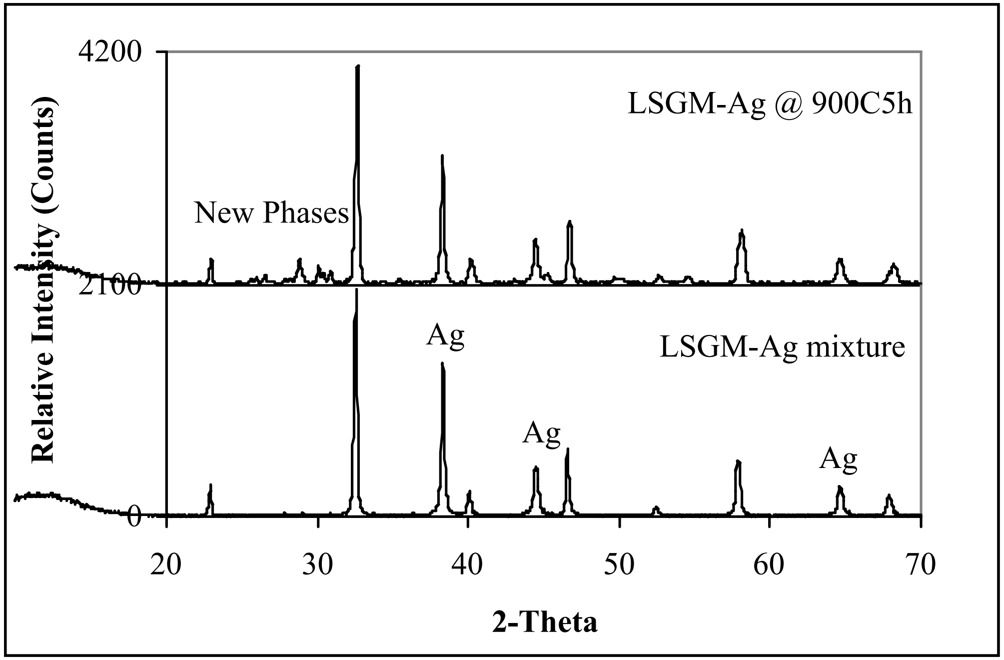
LSM

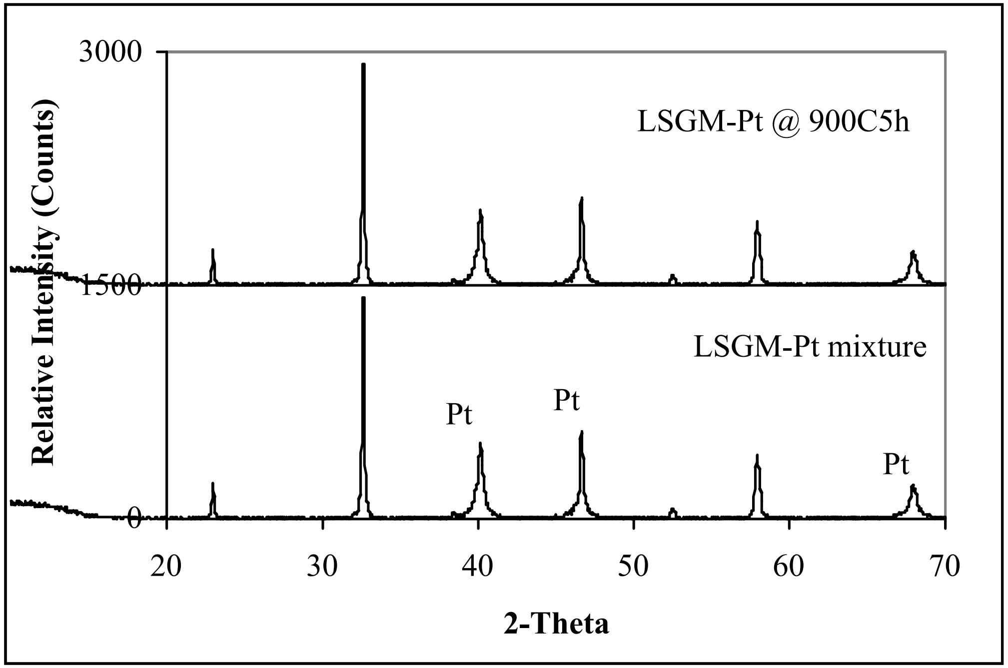
LSGM-LSM reaction couples at different temperatures.

$La_{0.8}Sr_{0.2}MnO_3$

$La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_{2.85}$

Reactivity with Ag or Pt?





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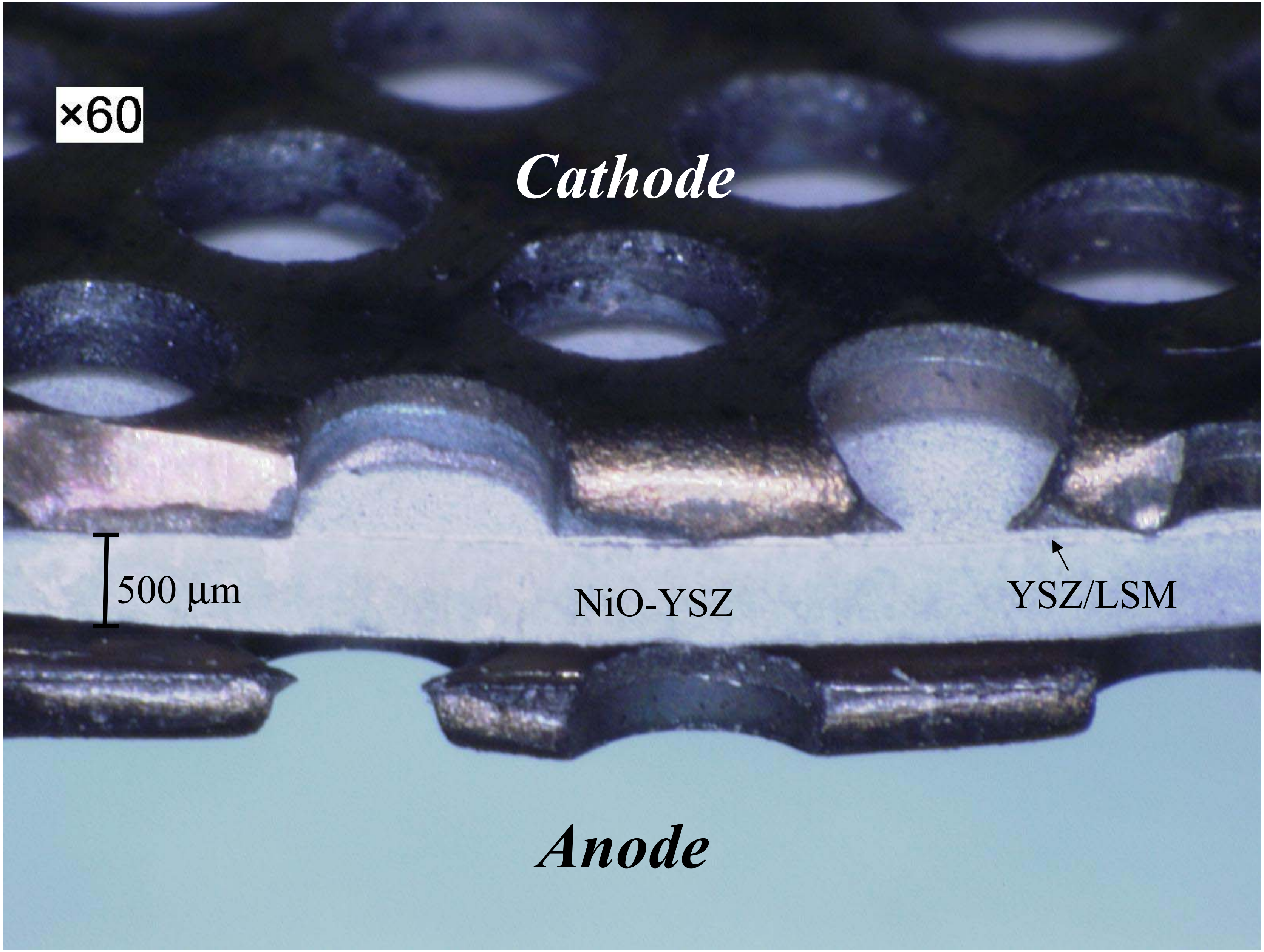
Metal Bonded SOFC - Edge View



Summary

- Significant cost reduction for SOFCs can be realized through metal supported designs, both in terms of raw materials and design flexibility
- Electrode/electrolyte reactivity issues can be solved in some cases by switching from anode to cathode supported designs.
- Single-step sintering of thin-film, electrode-supported cells has been demonstrated.
- LSGM reacts with everything.
- Metal supported SOFCs fabricated by post-sintered bonding offers significant advantages in terms of simplified sealing, robust mechanical properties, and very low cost of raw materials.