Cathode Infiltration

Steve Visco
Hideto Kurokawa, Mike Tucker,
Tal Sholklapper, Xuan Chen, Ken Lux
Craig Jacobson, Lutgard De Jonghe

Lawrence Berkeley National Laboratory
Berkeley, California USA

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Core Technology Program – Electrodes and Contaminant Issues
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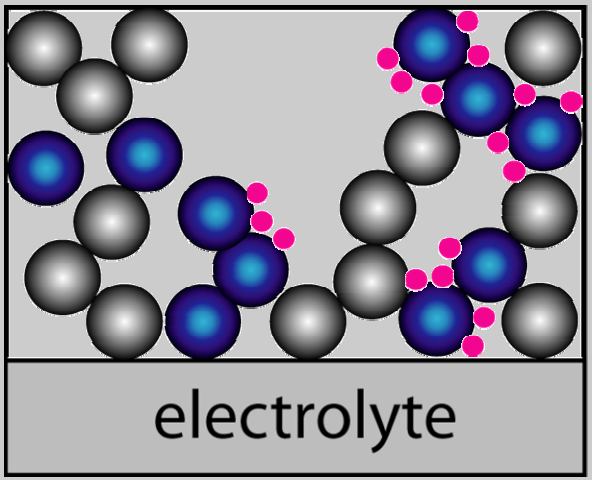
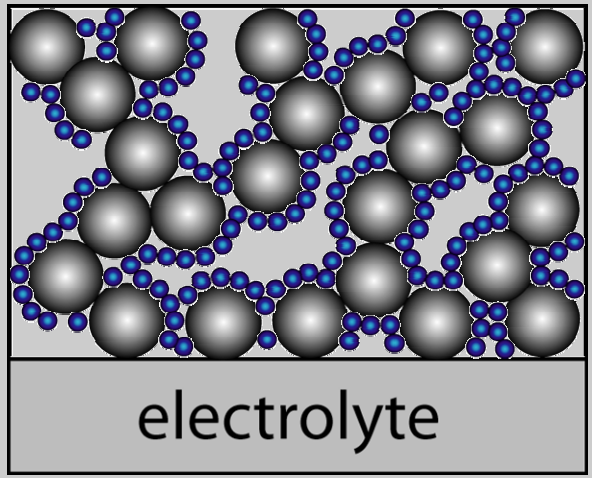
Improvement of Air Electrode Low Temperature Performance

Simple metal nitrates

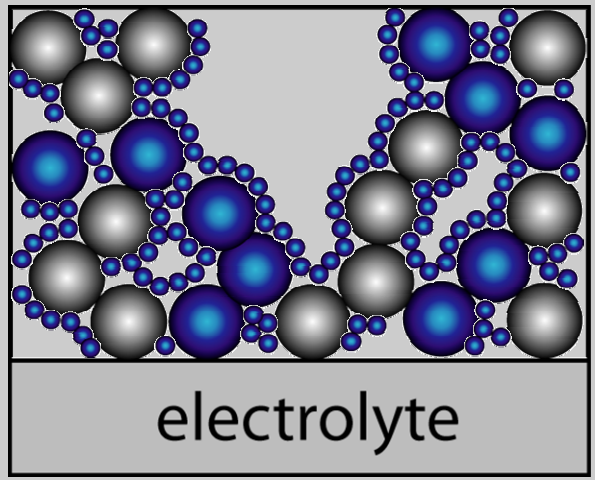


Introduce oxides that would otherwise react at the firing temperature: $Sm_{0.6}Sr_{0.4}CoO_{3-x}$, $La_{0.6}Sr_{0.3}Co_{0.8}Fe_{0.2}O_3$, etc.

Surfactant dispersed electrode precursors



Porous electrolyte matrix



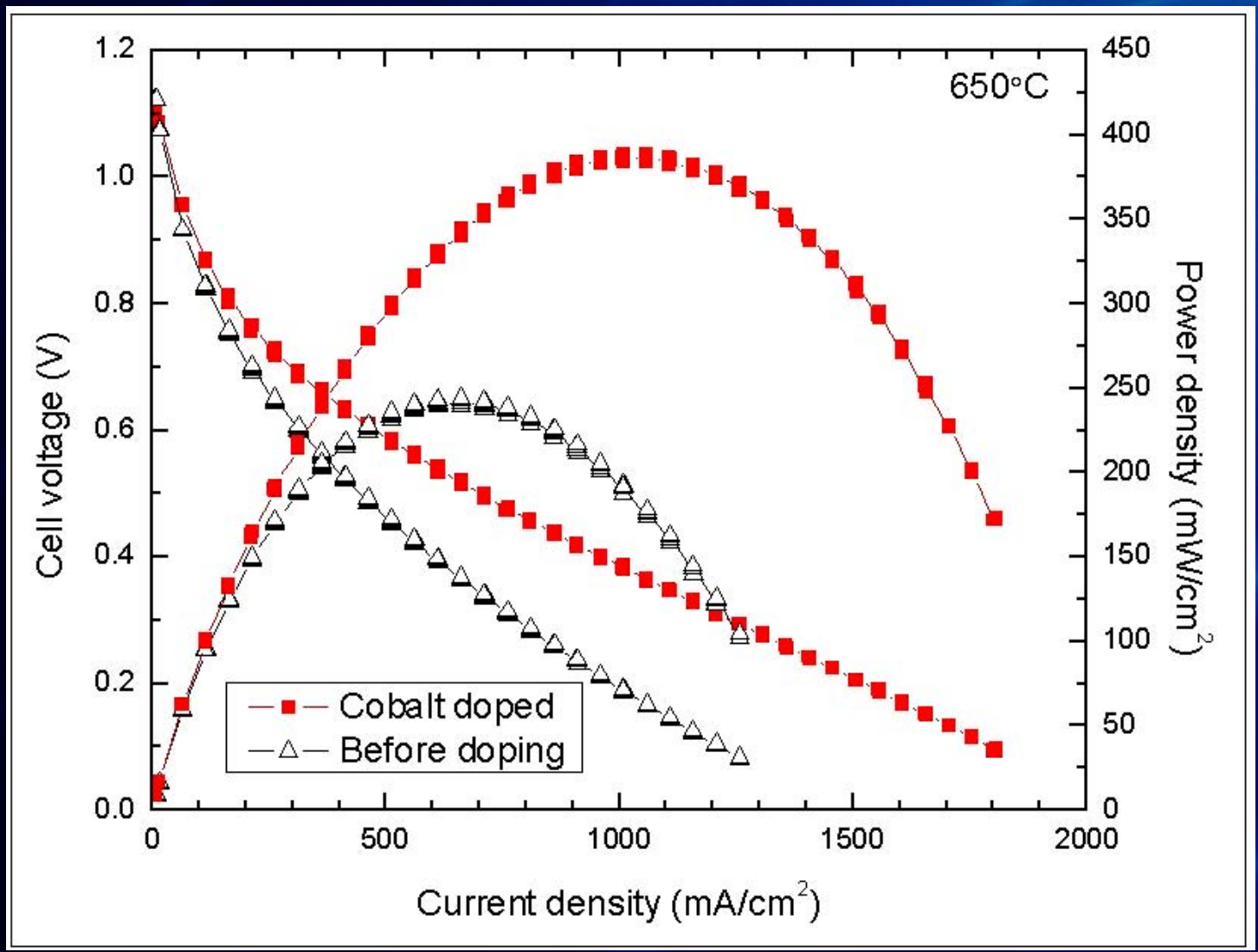
Composite Commercial electrodes (YSZ-LSM)

electronic conductor

ionic conductor

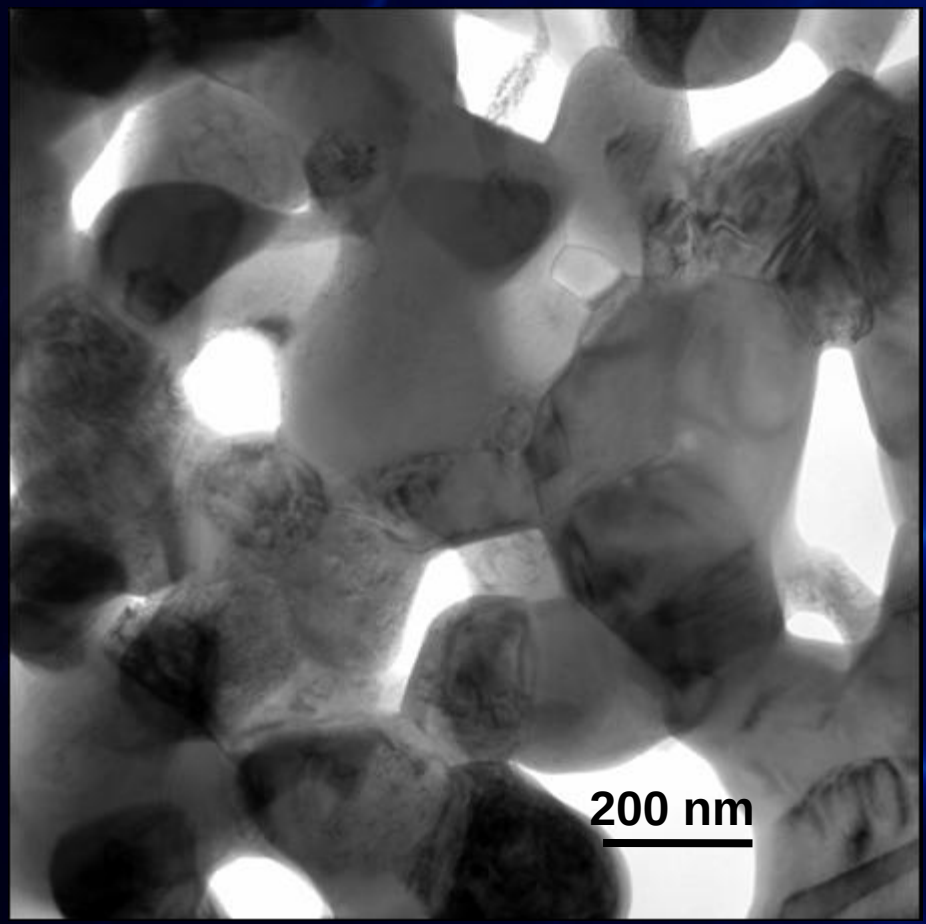
catalysts

Power density was improved by as much as ~2 times at 650°C by cobalt doping of cathode using a simple infiltration method.

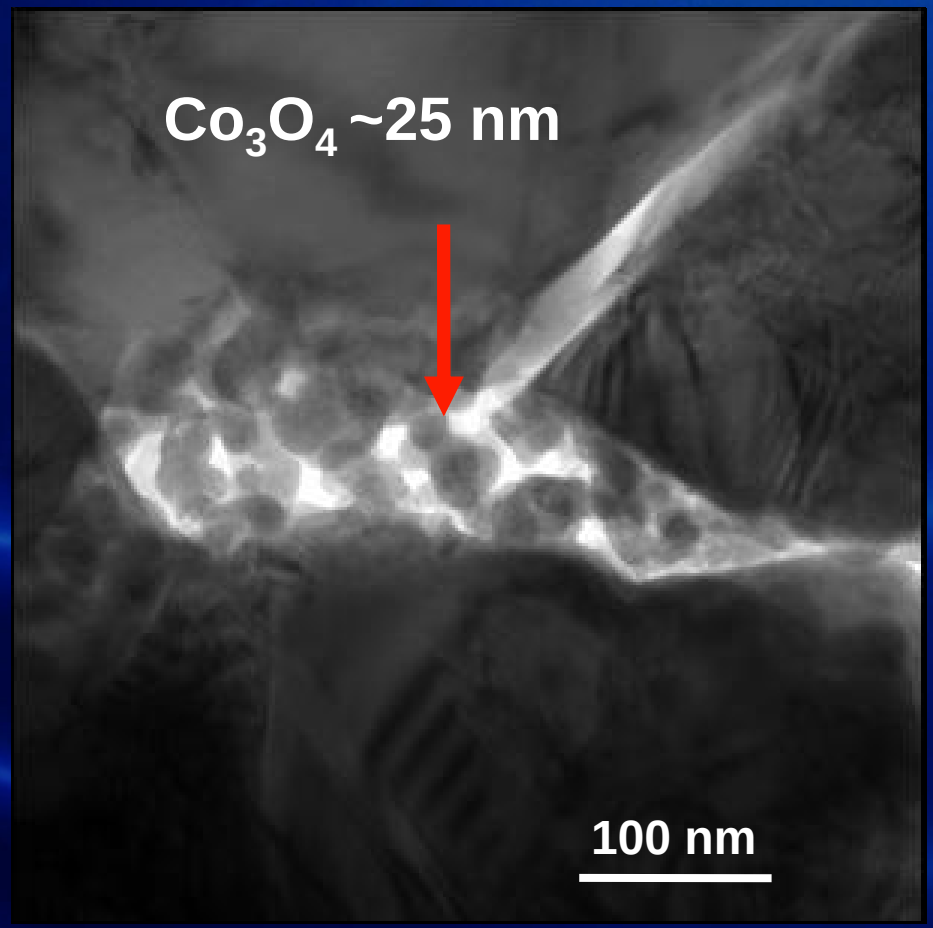


TEM: Co_3O_4 Particles in the Pores of LSM-10Sc1YSZ Composite

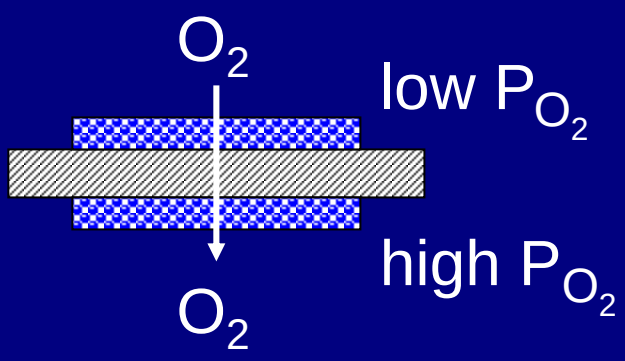
Before Doping

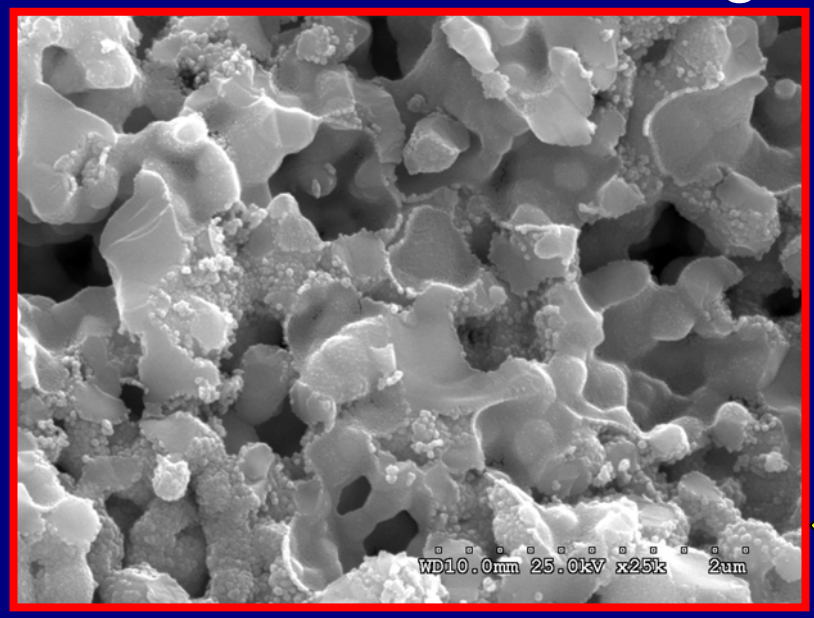


Cobalt Doped



LSM-YSZ electrode infiltrated with 20mg/cm^2 Co Nitrate





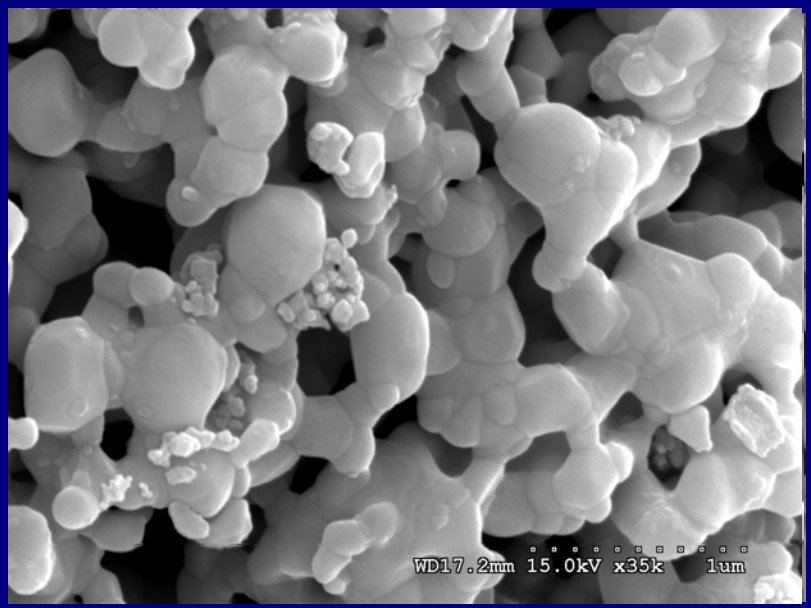
anode

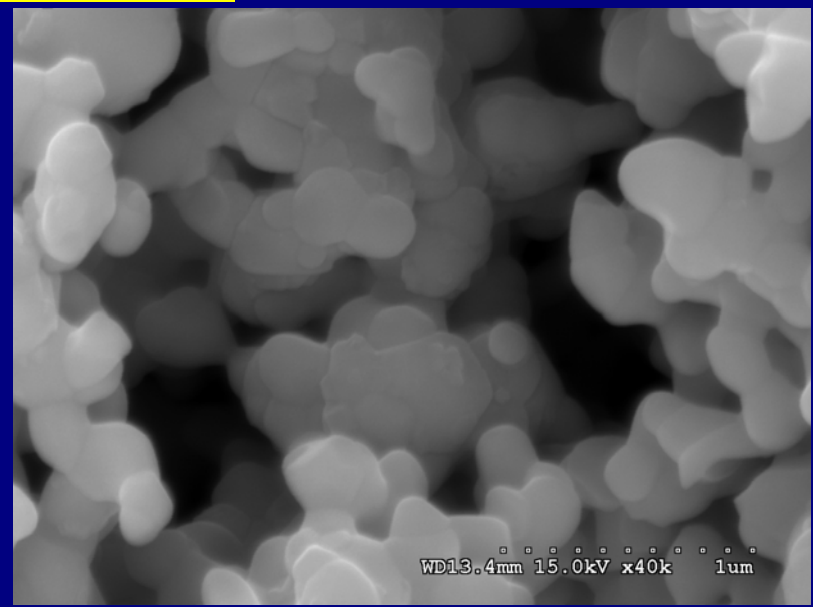
cathode

high P_{O_2}

3A/cm^2 at 800^{o}C

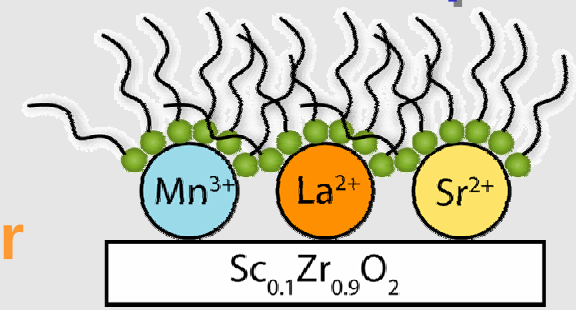
low P_{O_2}



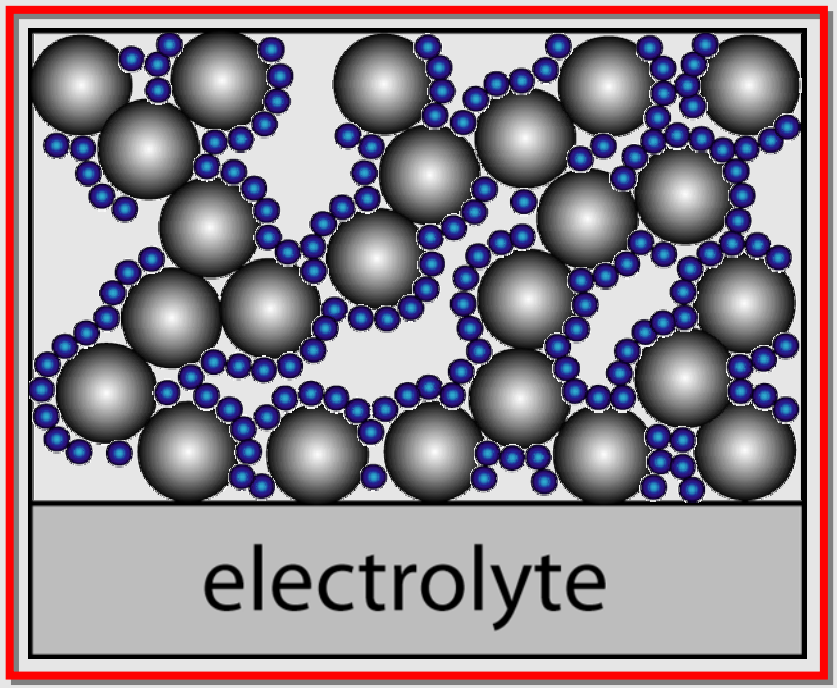


Infiltration Step

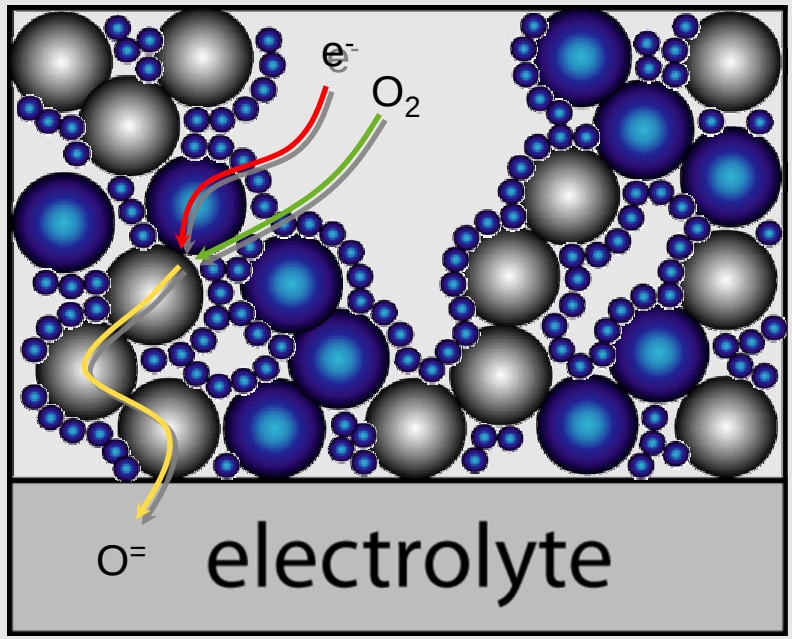
Nitrate-Surfactant Concentrated Precursor



Surfactant dispersed Electrode Precursors



Porous electrolyte matrix



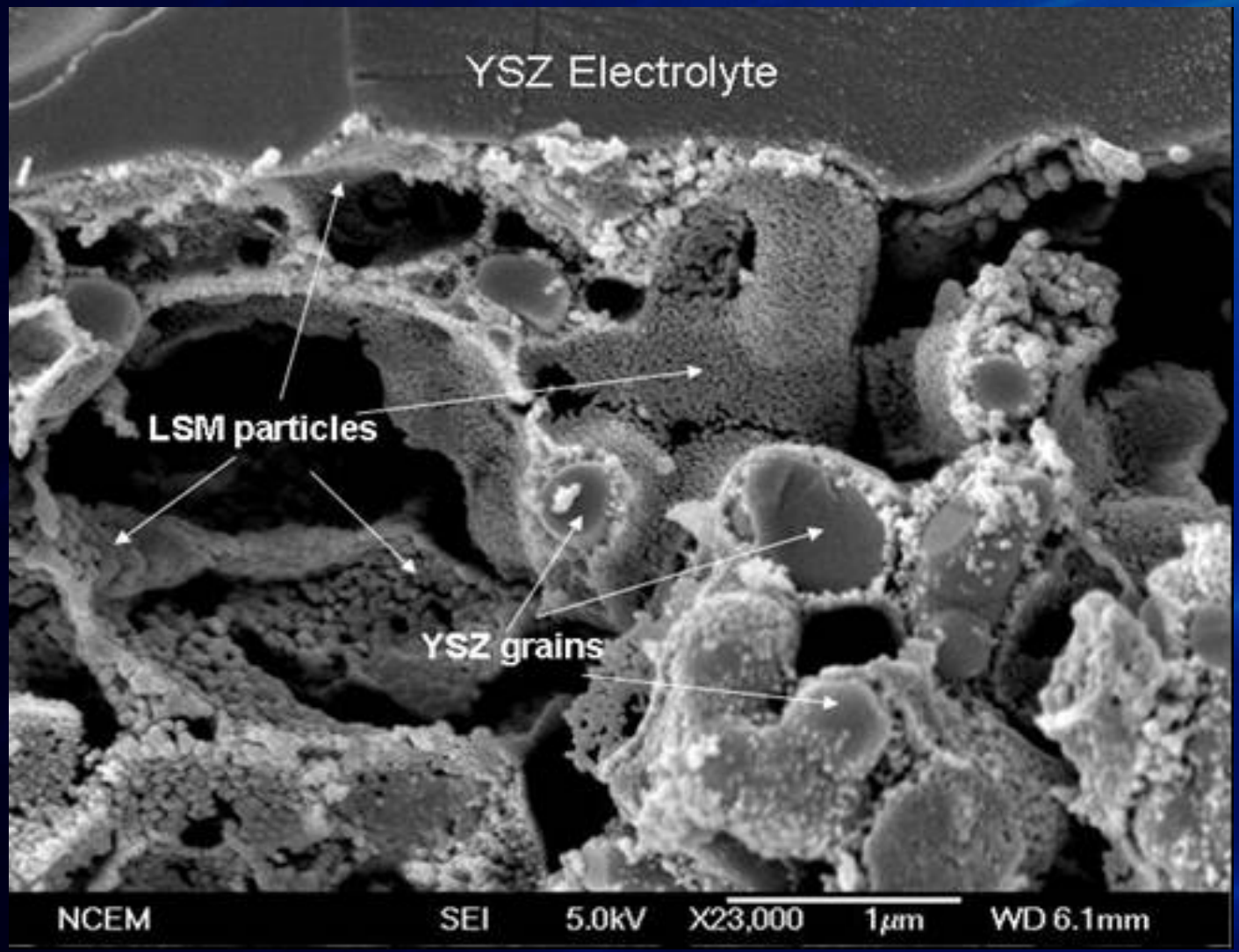
Composite Commercial electrodes (YSZ-LSM)

electronic conductor ionic conductor

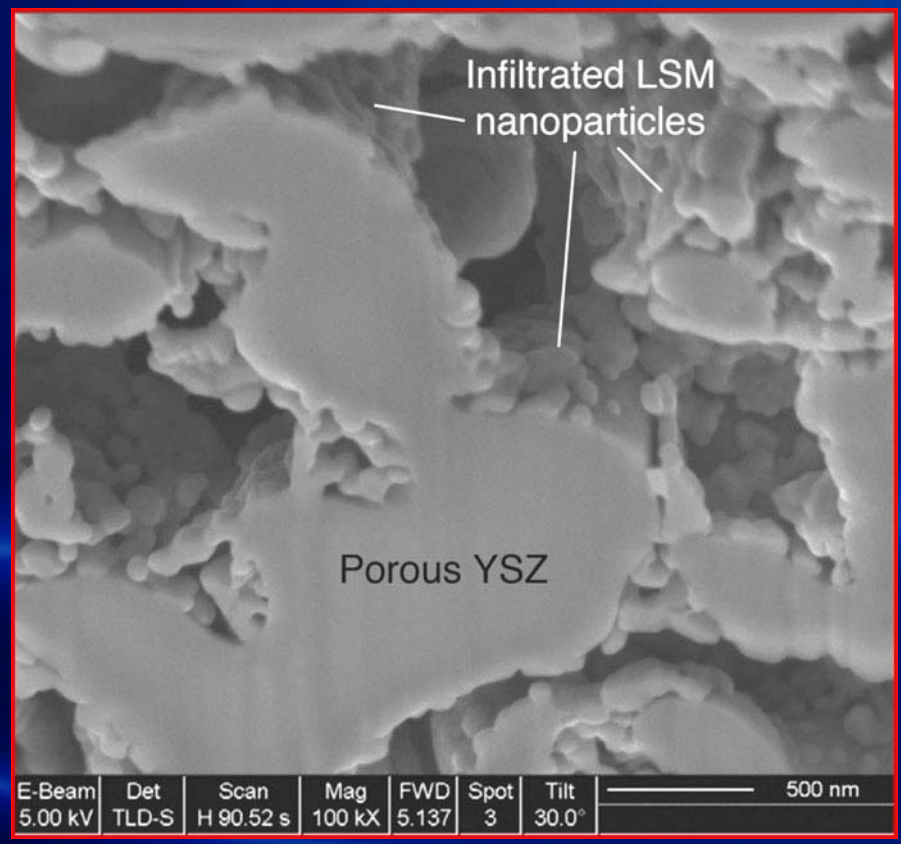
Nano-particulate SOFCs

- Technology involves vacuum impregnation of concentrated perovskite electrode (or electrolyte) precursor solutions that can generate the entire electrode in a single infiltration step.
- Can be used to fabricate unique electrode microstructures:
  - Nanoparticulate network infiltrated into **porous electrolyte** (allows stack fabrication in reducing atmosphere followed by introduction of perovskite structure) - nanoparticulate network must be continuous for electron path.
  - Nanoparticulate network deposited onto **existing electrode** (to improve low temperature performance) - existing LSM network used for current collection, expands reaction surface area.
- LBNL has used this approach to improve the performance of conventional electrodes and to fabricate unique structures
- LBNL is refining the technology to control the depth of penetration into porous structure and size of resulting nanoparticles

Nanoparticulate SOFC Electrodes

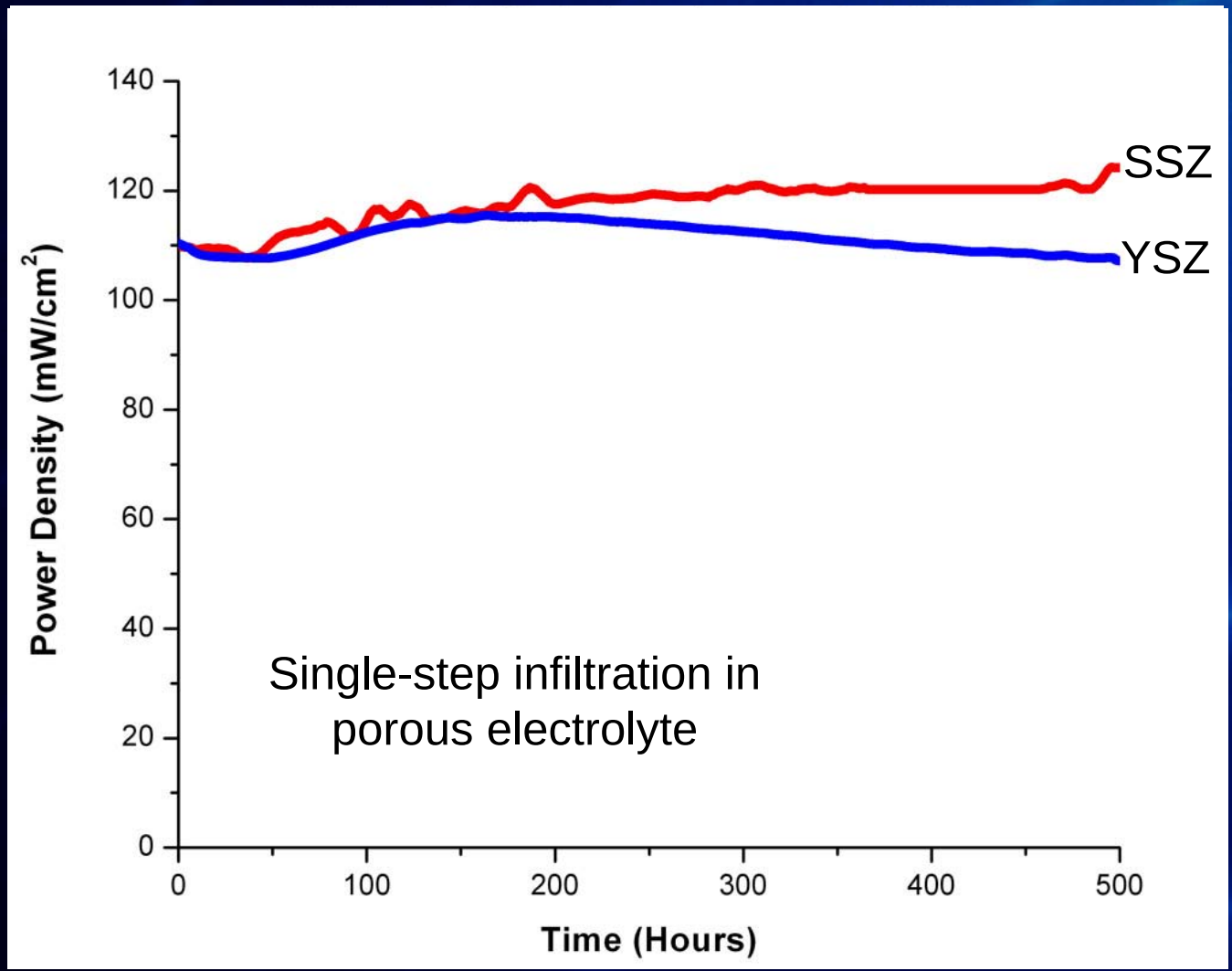


Focused-ion-beam (FIB) trench showing cross-section of single-step LSM infiltrated thin-film SOFC

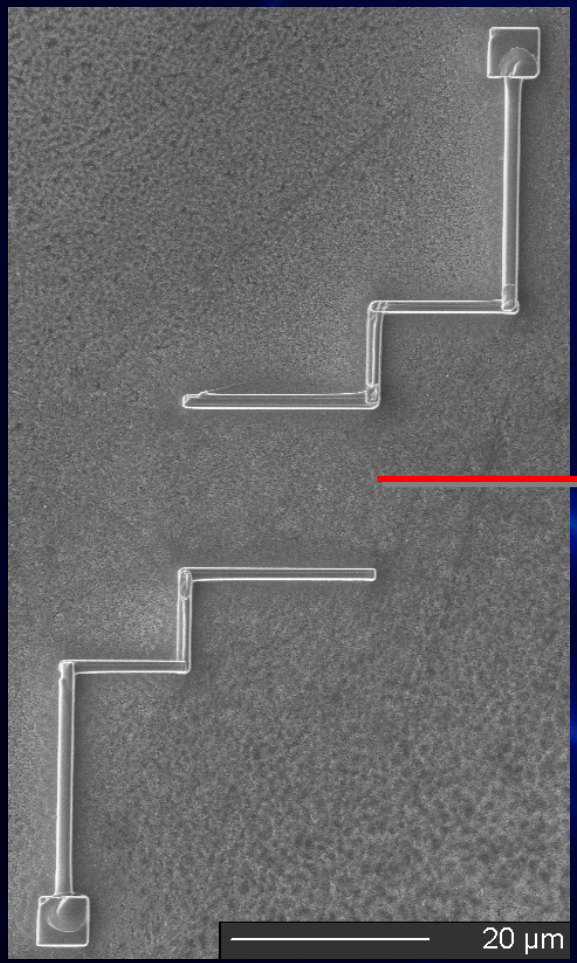


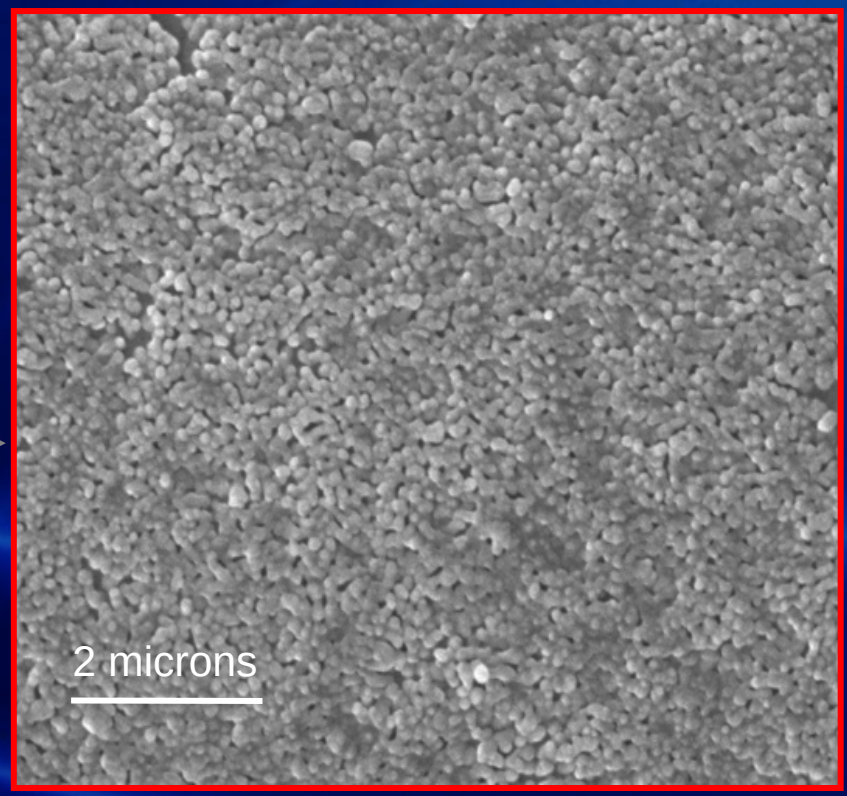
Infiltrated cathode after 500 hours continuous operation at 650 ^{o}C

Performance & Stability of Nanoparticulate Electrodes at 650 °C

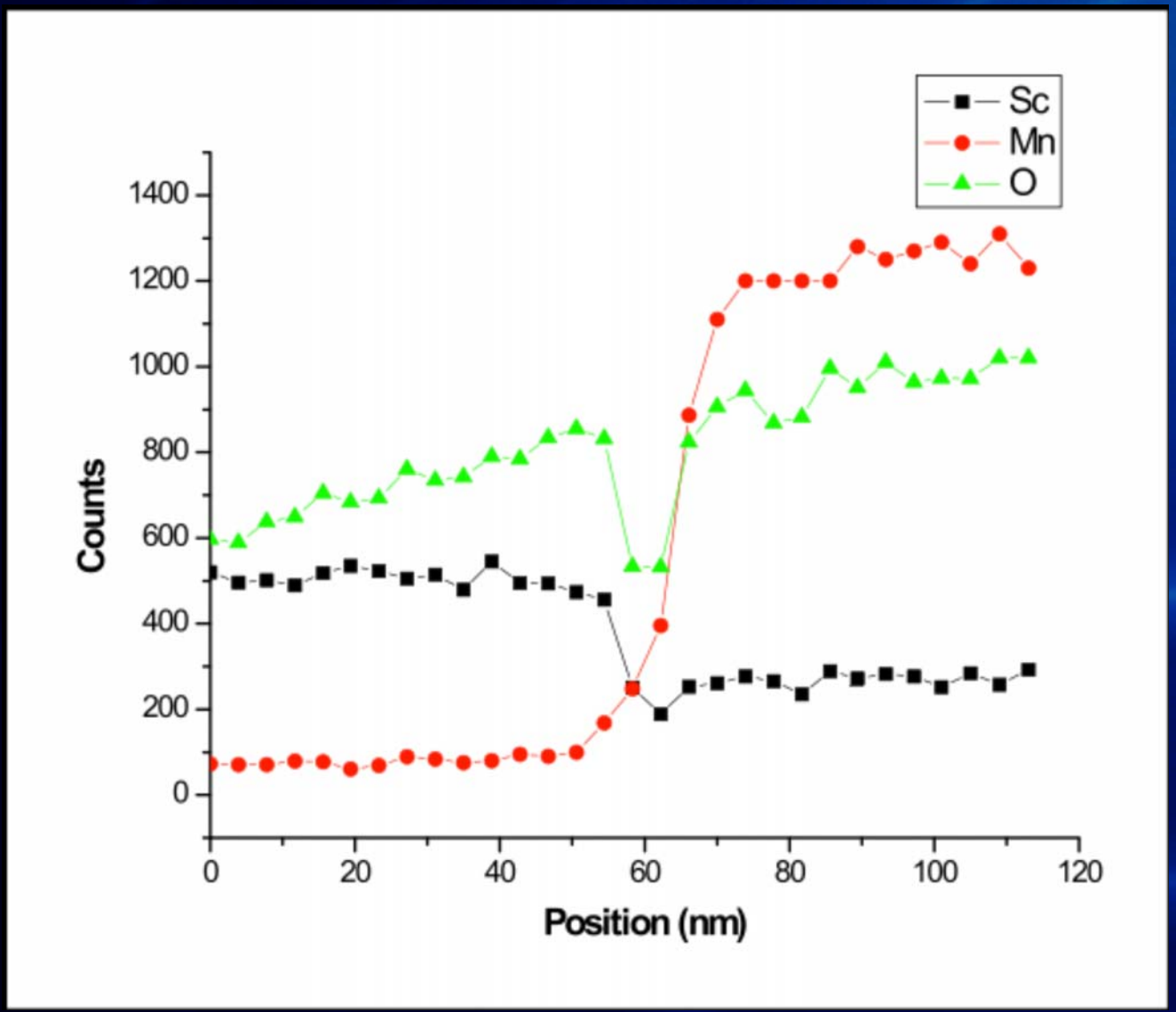


Supported 2-D Monolayer of Particulate Catalyst LSM Network with Electronic Probes





EDX Line Scan SSZ to LSM



Infiltration Step

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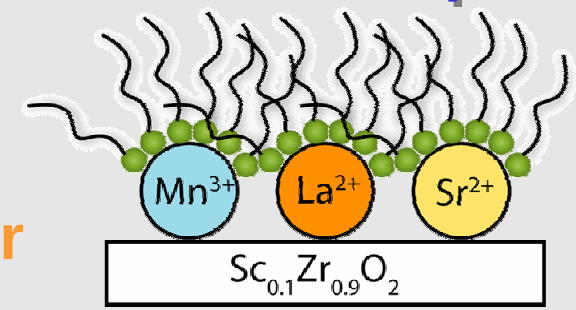
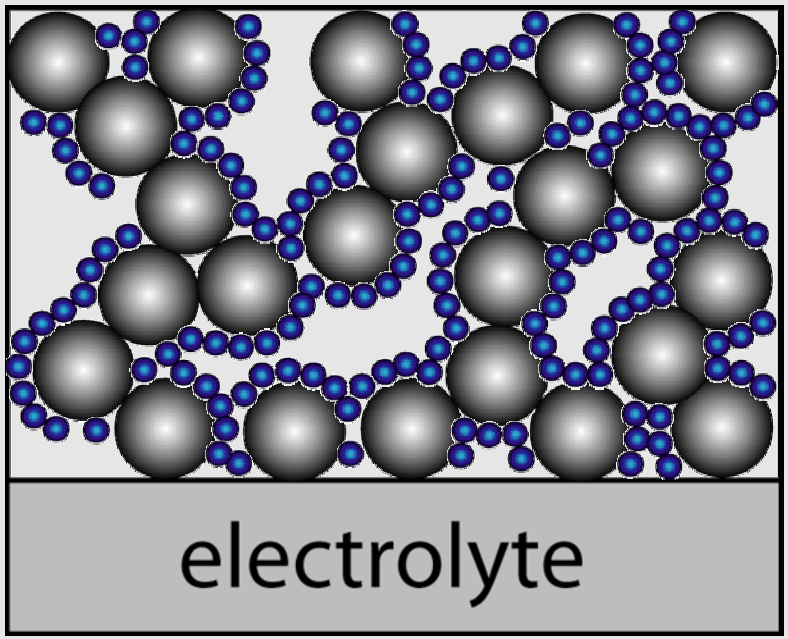
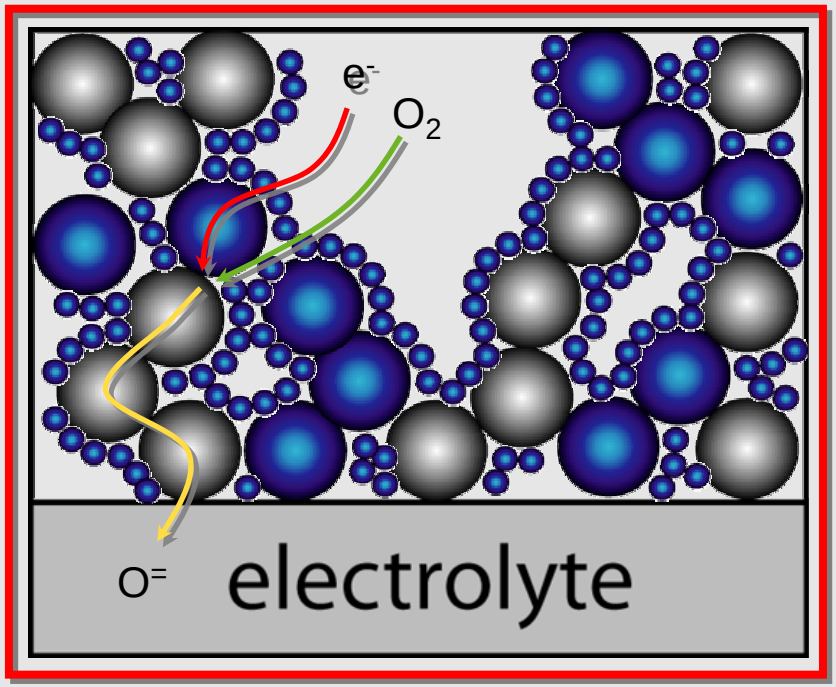


Surfactant dispersed Electrode Precursors



Porous electrolyte matrix



Composite Commercial electrodes (YSZ-LSM)

electronic conductor ionic conductor

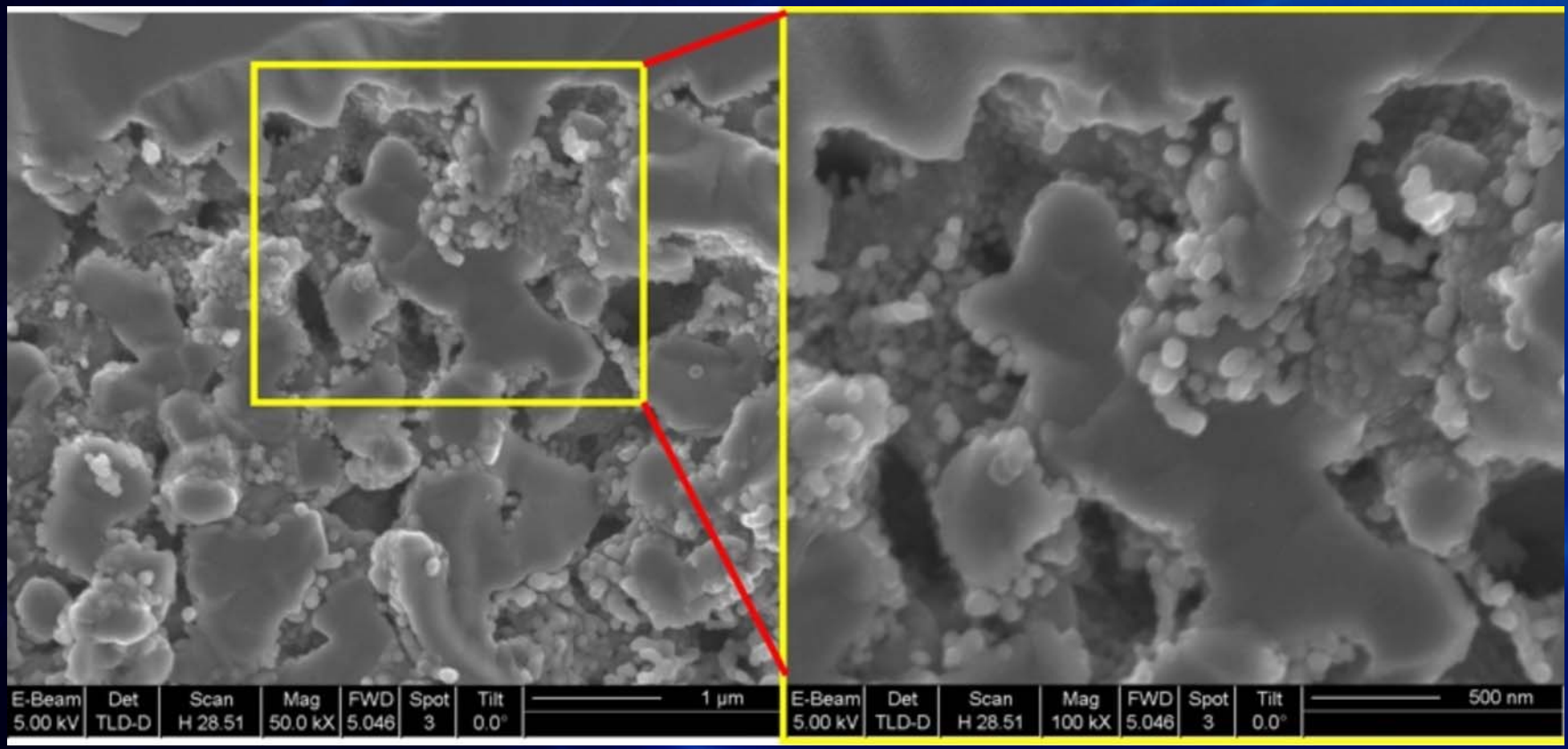
Commercial Symmetric Electrolyte Supported LSCF Cell from INDEC
LSCF-YDC/TZ3Y/YDC-LSCF

H.C. Starck HCST
Engineered Material Solutions

InDEC B.V.

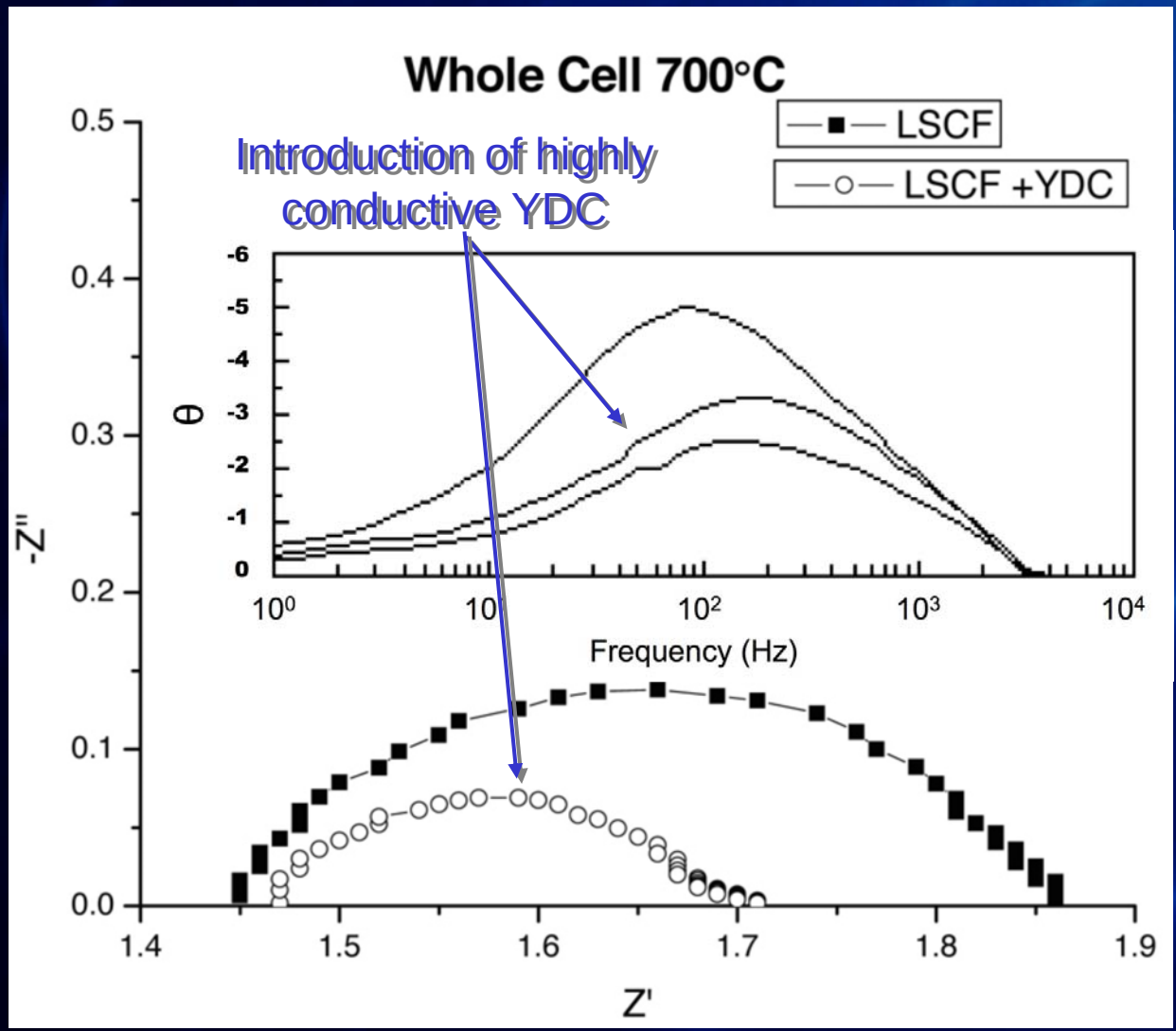
Infiltration of LSM Nanoparticles into LSM-YSZ Composite

50 kX 100 kX

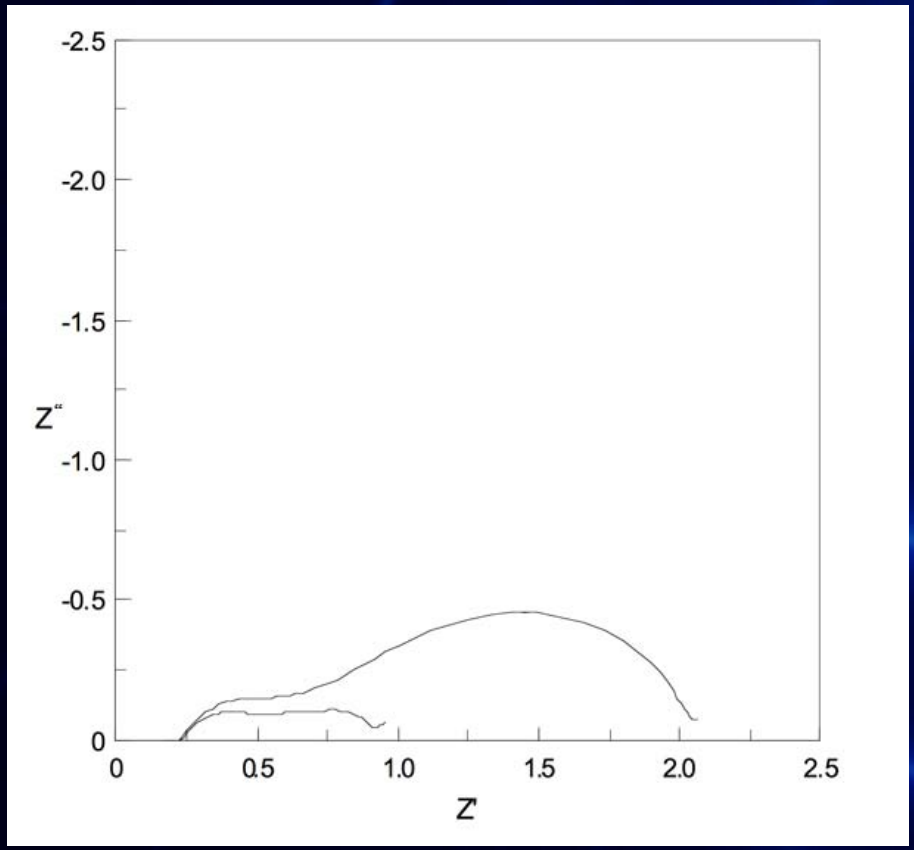


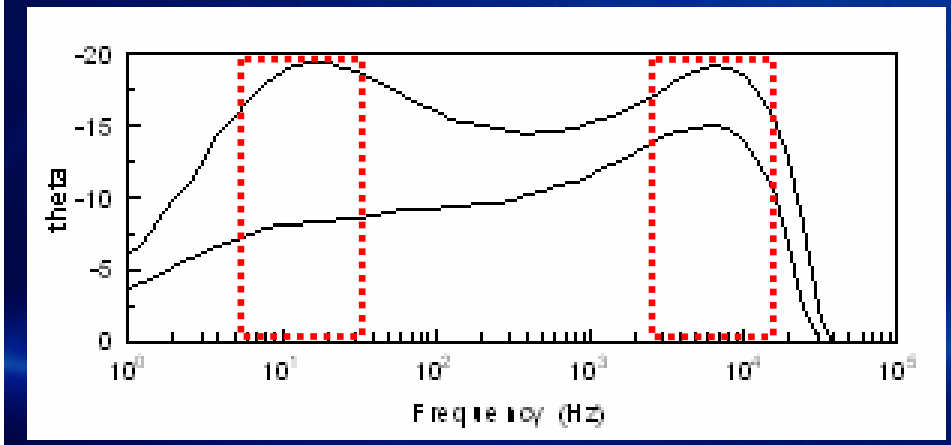
SEM Image of LSM-YSZ composite sintered at 1200°C for 4 hours, then infiltrated with LSM-surfactant precursor and fired at 900°C for 1 hour

Commercially Produced Cell - InDec, (LSCF-YDC/TZ3Y/YDC-LSCF) W/ and W/out YDC Connected Nanoparticulate Infiltration

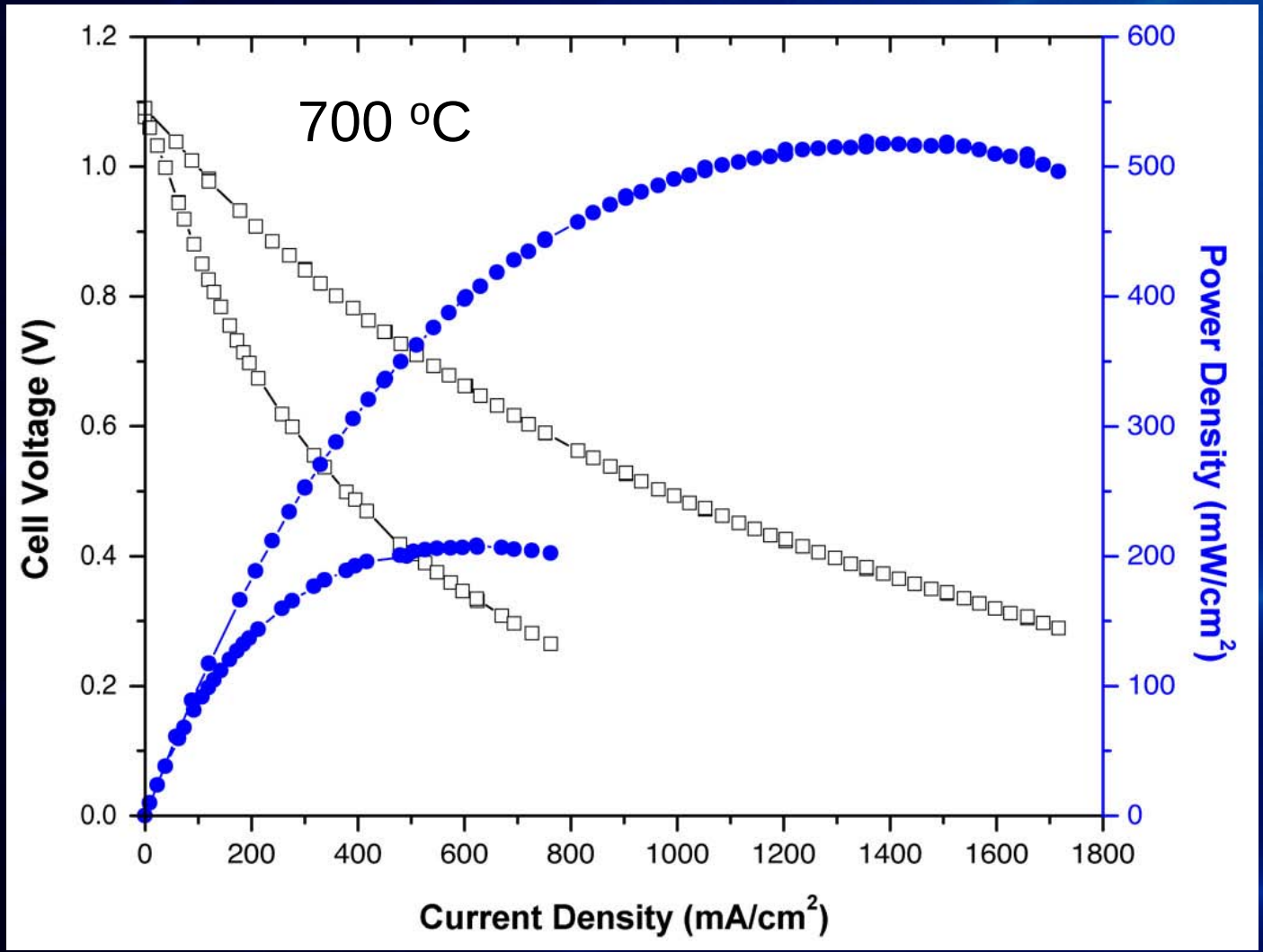


Anode supported Ni-YSZ/YSZ/LSM-YSZ cell infiltrated with YDC Cell Impedance at 700 ^{o}C





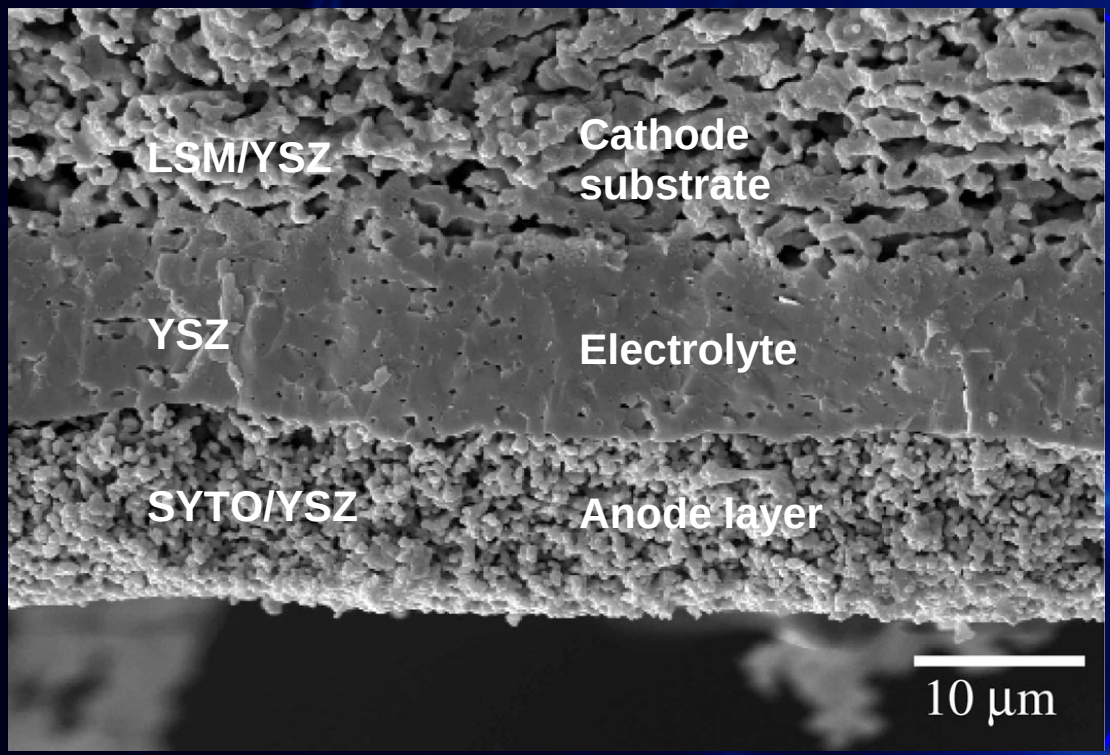
Anode supported Ni-YSZ/YSZ/LSM-YSZ cell infiltrated with YDC
Cell Performance at 700 ^{o}C

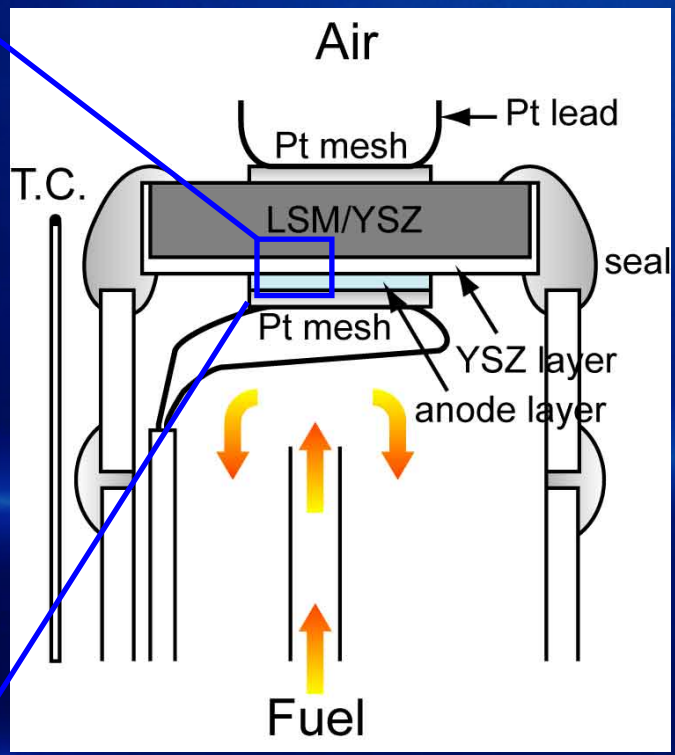


Sulfur-tolerant Anode with Single-Step infiltration

Sulfur-tolerant, cathode supported cell with an SYTO/YSZ anode was developed and the performance improved with infiltration of CeO_2 and Ru.

Cross section of cathode supported cell



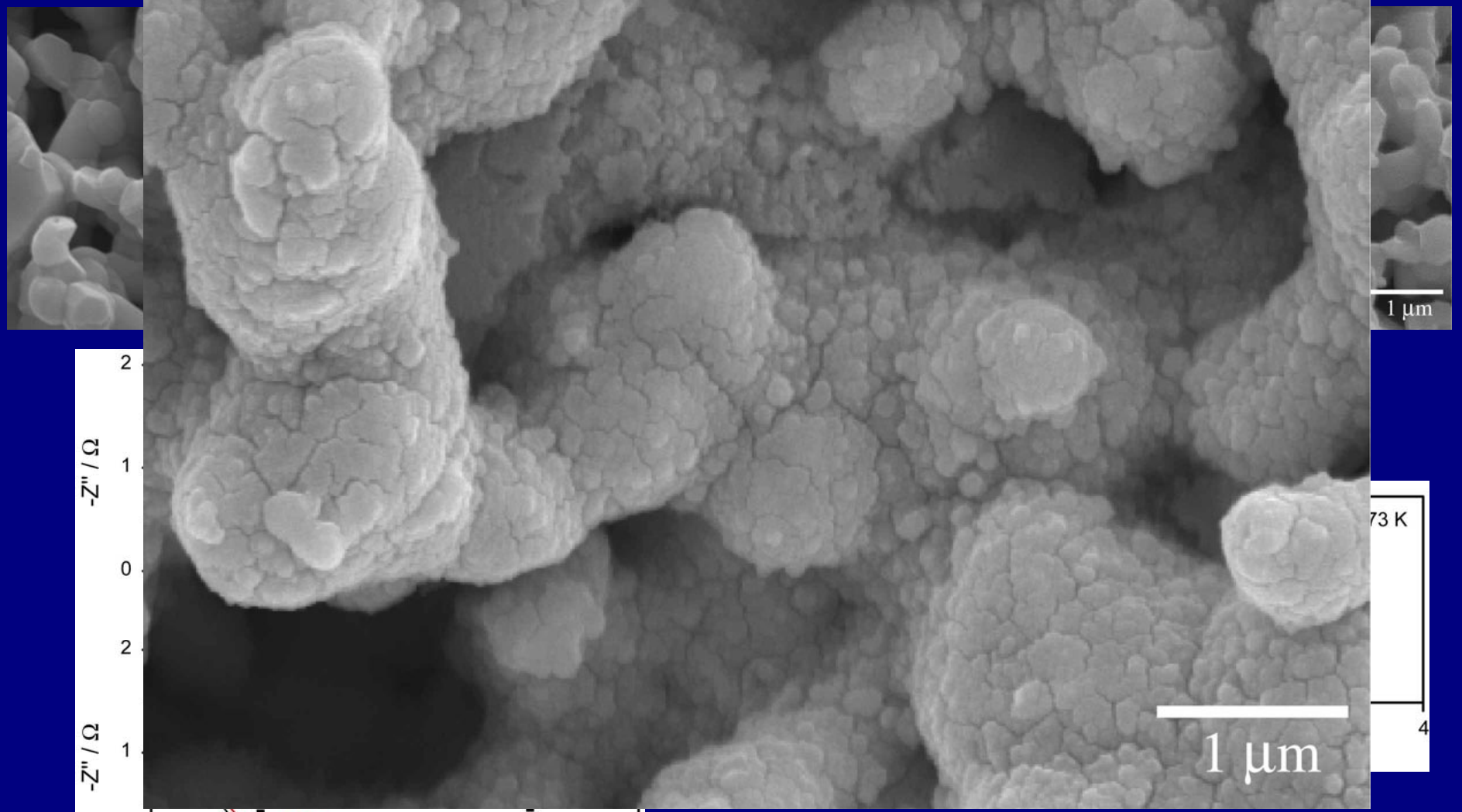


See Ray Gorte's work on SYTO/CeO_2/Ru

The effect of single-step infiltration on sulfur-tolerant anode

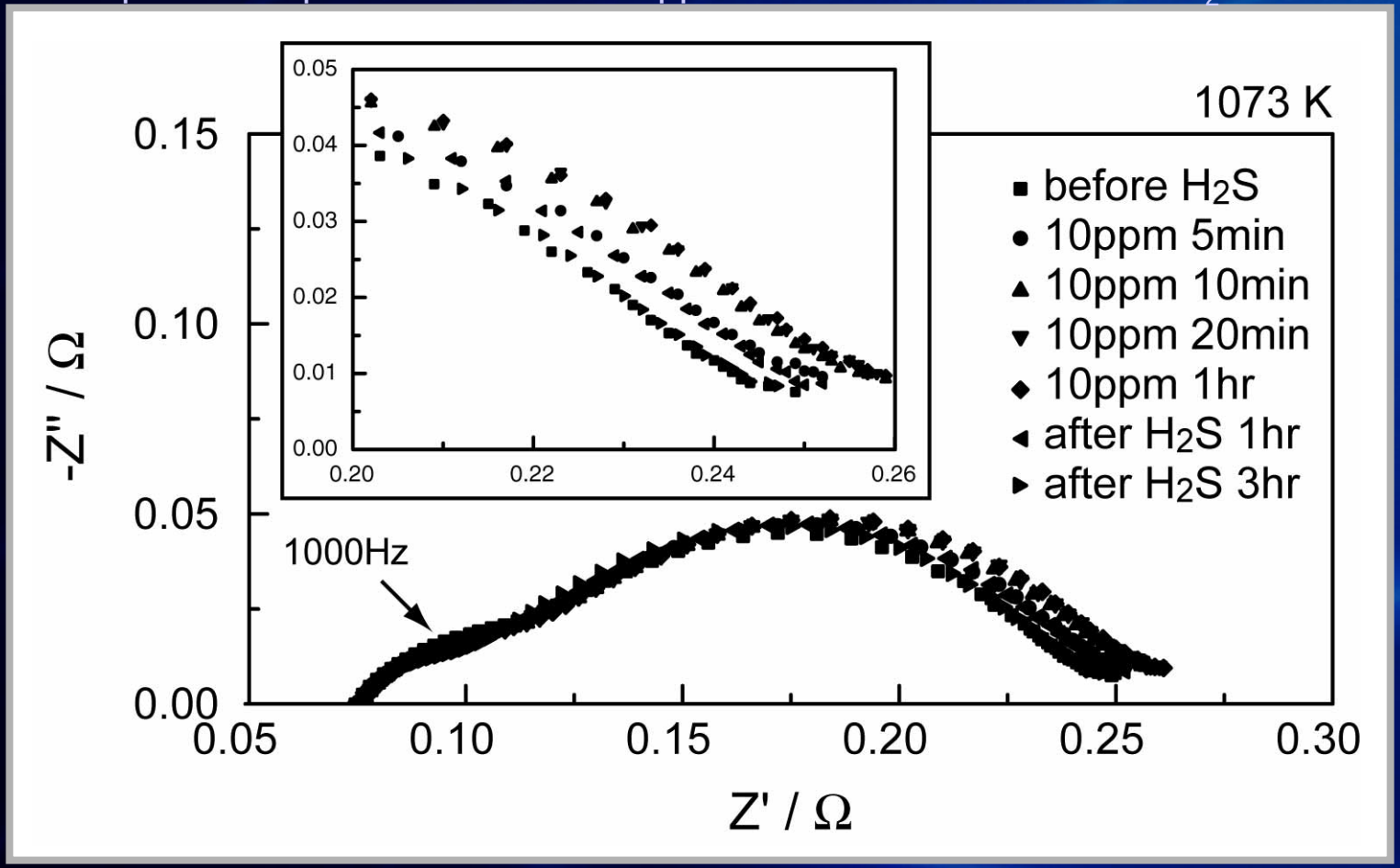
- **SYTO/YSZ + dispersed catalytic materials (on 500μm YSZ disk)**

SYTO with



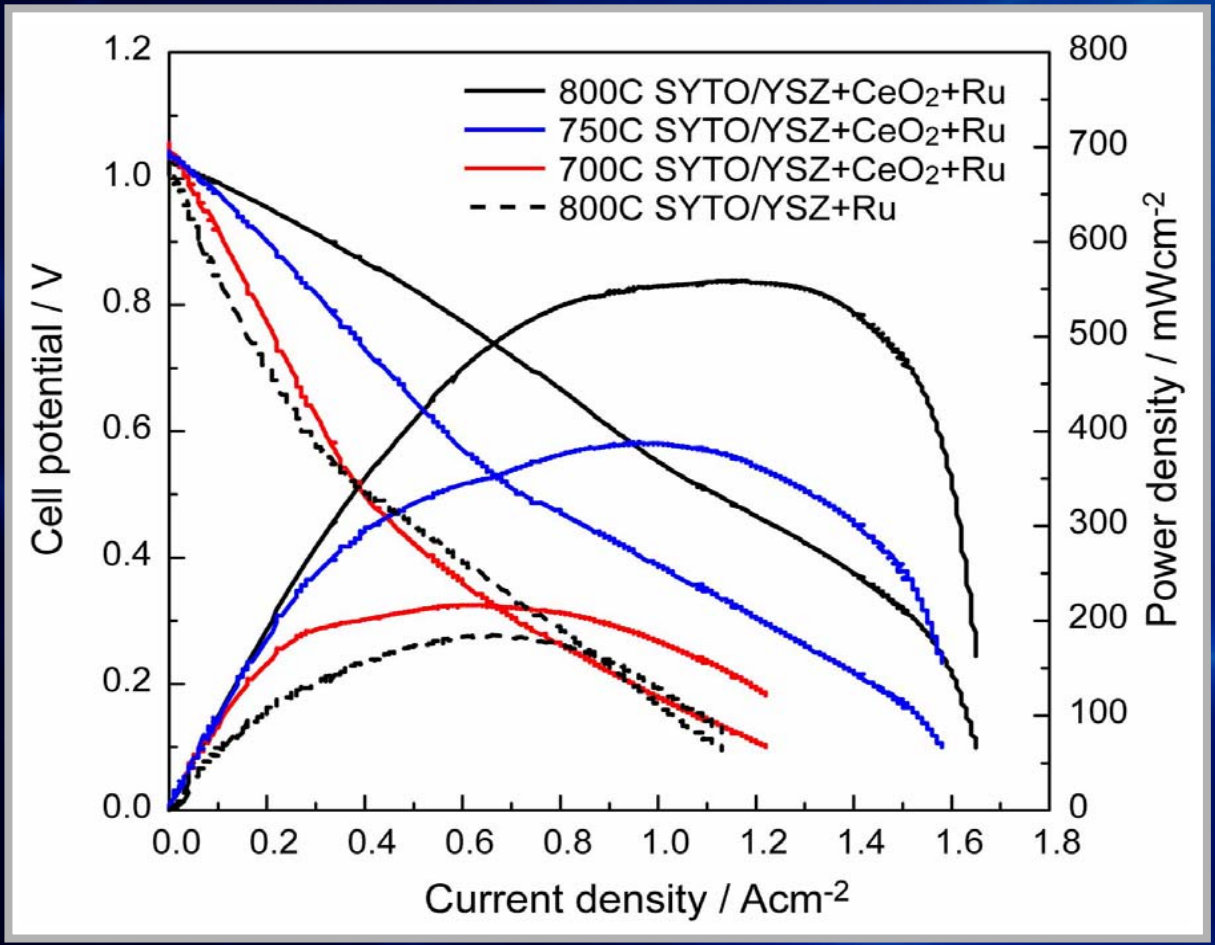
Sulfur tolerance of SYTO/YSZ+CeO_2+Ru anode

AC Impedance spectra of cathode support cell with SYTO/YSZ+CeO_2+Ru anode



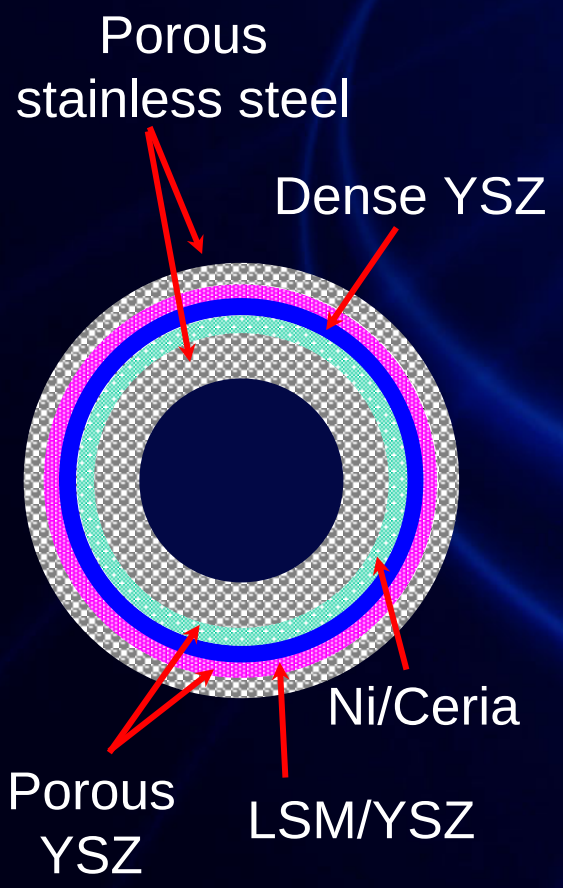
SYTO/YSZ+CeO_2+Ru anode was not affected by H_2S very much and completely recovered in H_2/H_2O.

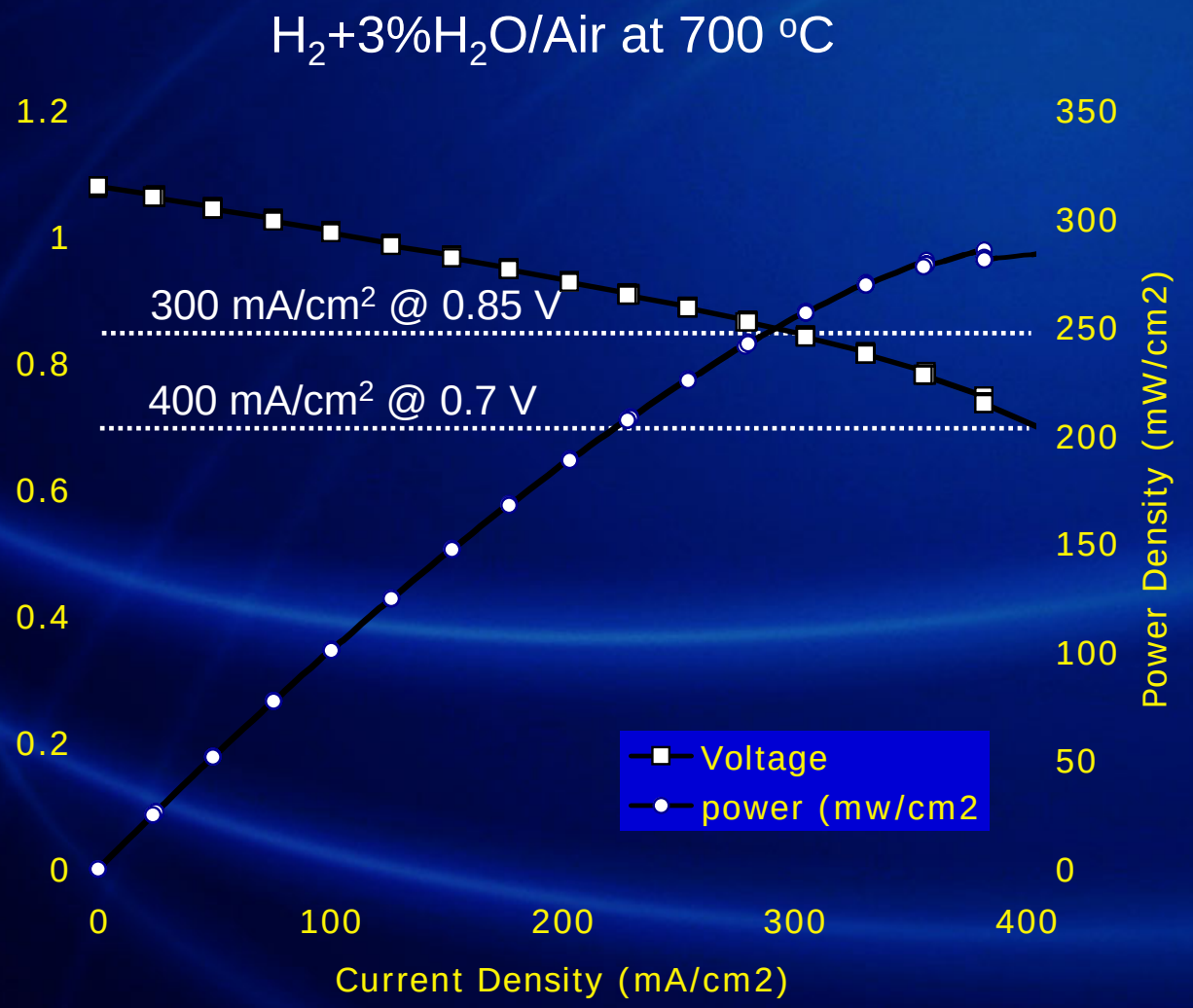
Performance of Single-Step Infiltrated, Cathode-Supported, Sulfur Tolerant Cell at 700 to 800 ^{o}C



The cell with CeO_2/Ru infiltration showed **200 mW/cm^2** at 700 ^{o}C and **550 mW/cm^2** at 800 ^{o}C

Metal Supported Tubular SOFC w/Infiltrated Electrodes





Team:

Investigators:		
	Steven Visco	P.I. Program Lead
	Lutgard De Jonghe	Co-PI
Scientists:		
	Peggy Hou	High temperature corrosion
	Velimir Radmilovic	NCEM FIB/SEM/TEM
Post Doc:		
	Hideto Kurokawa	Cr transport phenomena
	Ken Lux	Air electrode stability
Senior Technical Staff:		
	Craig Jacobson	Processing and characterization
	Mike Tucker	Metal supported SOFC development
	Grace Lau	Processing and analysis
	Inna Belogolovsky	Processing and testing
Graduate Students:		
	Tal Sholklapper	Nano-particulate catalysts
	Liming Yang	Novel anode catalysts
	Xuan Chen	Infiltration of cathode catalysts

Acknowledgements

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- Thanks to Lane Wilson for helpful discussion and long teleconferences….