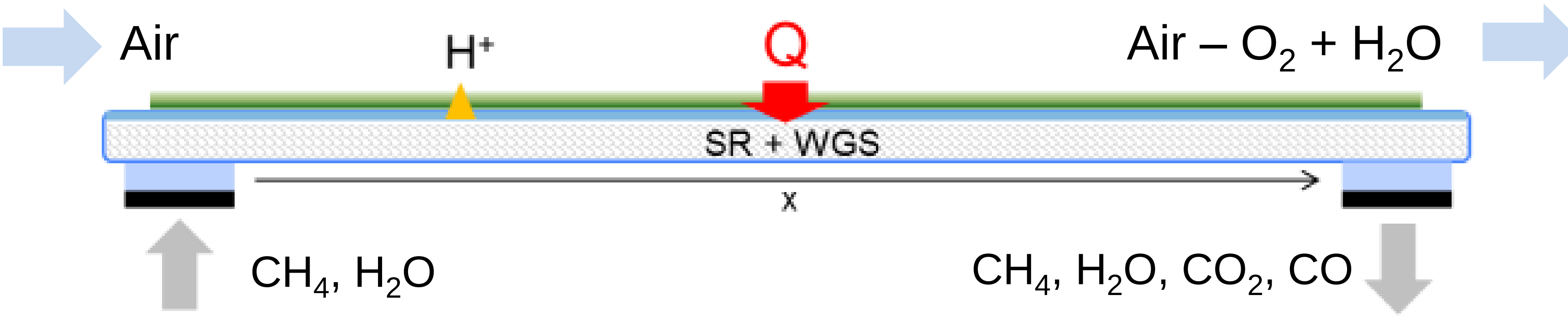
An Intermediate Temperature Metal-Supported Proton-Conducting Solid Oxide Fuel Cell Stack

18th Annual SOFC Workshop

June 14, 2017

Stack Concept

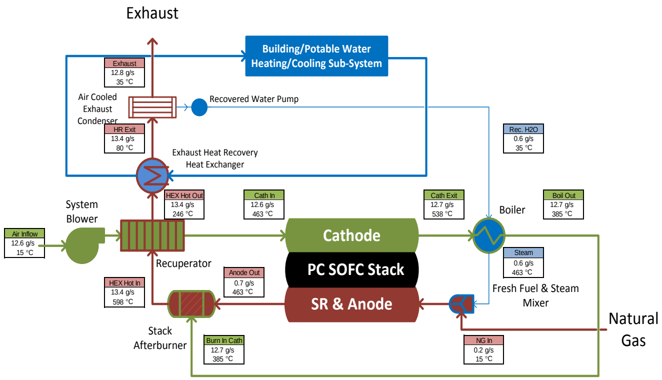
Metal supported p-SOFC with internal CH_4 reforming

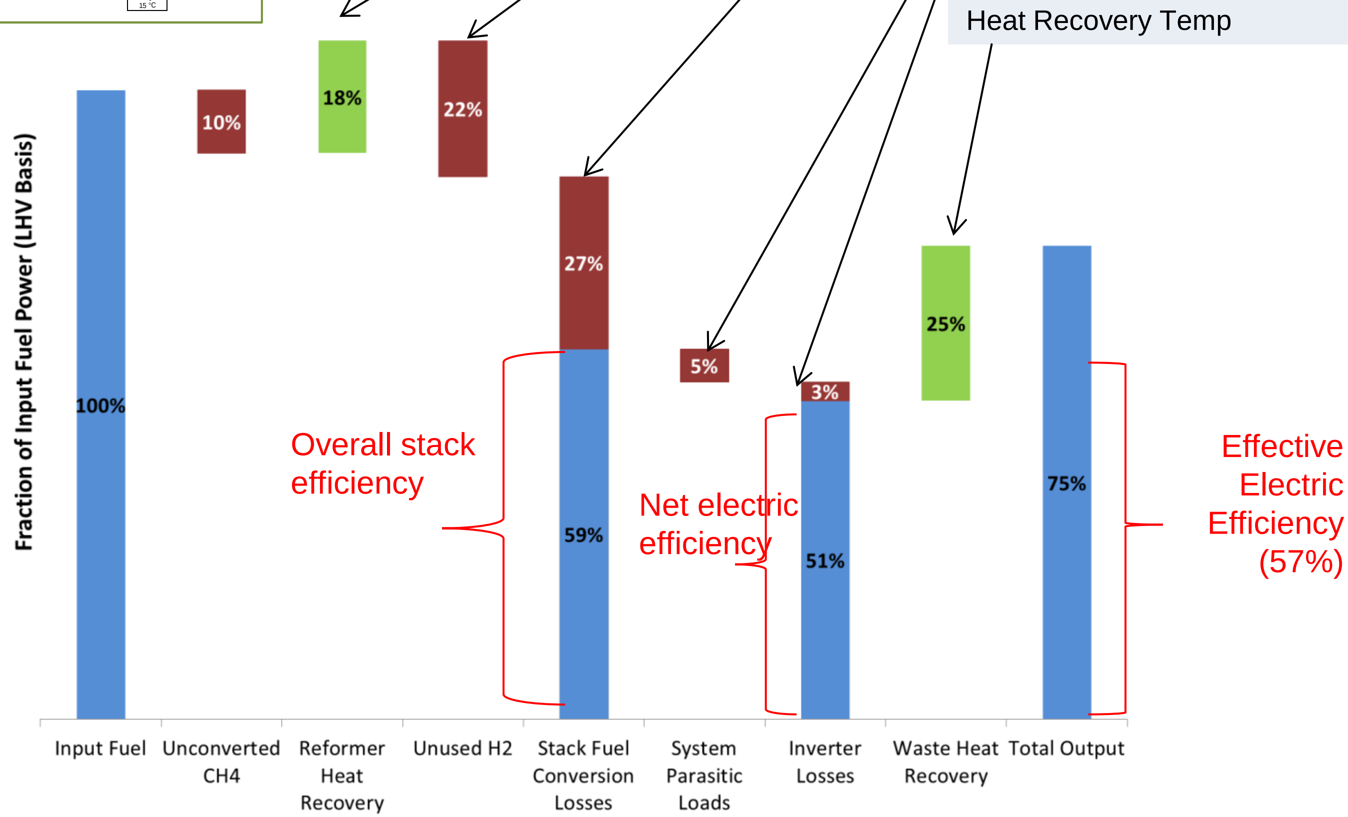


Feature	Lead Organizations
Proton-Conducting Oxide	Northwestern, University of Maryland, UCONN
Metal Support	ElectroChem Ventures, UCONN, United Technologies Research Center
Internal Fuel Reforming	United Technologies Research Center

CHP System Concept & Efficiency

Assumptions	
Methane Conversion	90%
H_2 Utilization	80%
OCV (V/Cell)	1.05
ASR (Ωcm^2)	1
Current Density (mA/cm^2)	200
Parasitic Power / Stack Power	9%
Inverter Efficiency	95%
Heat Recovery Temp	75 °C





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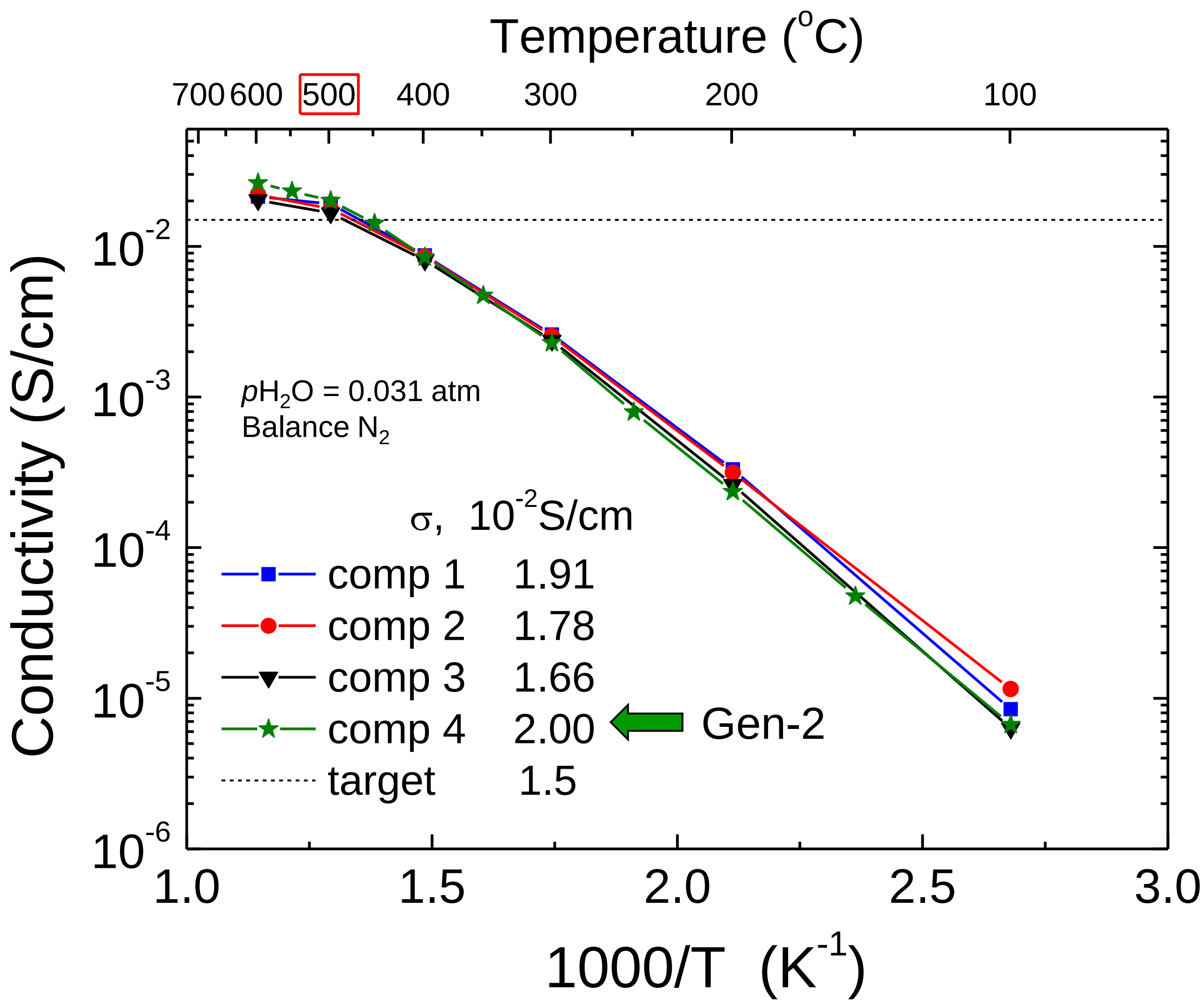
PCO-Electrolytes: Exceed Target Conductivity



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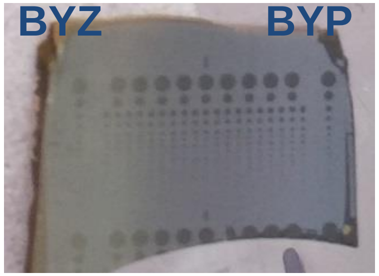
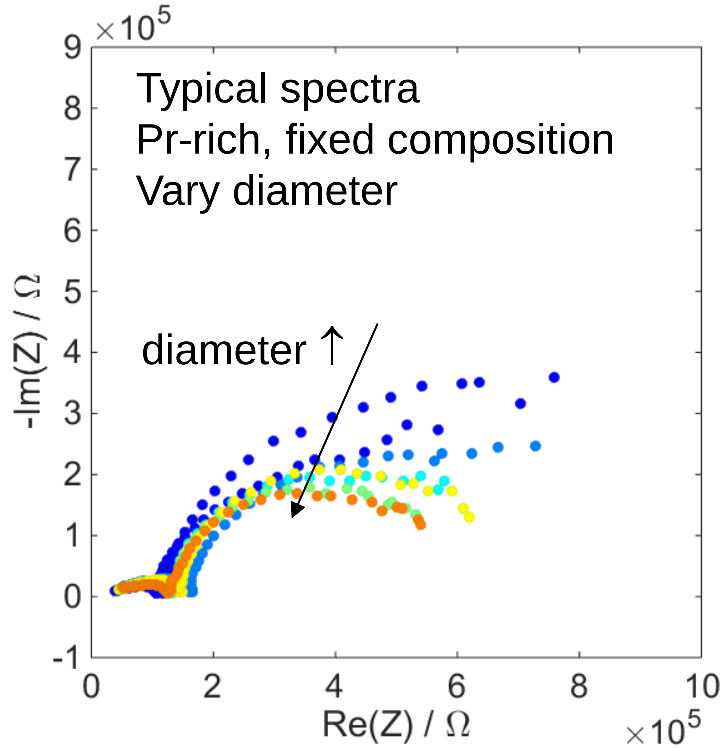
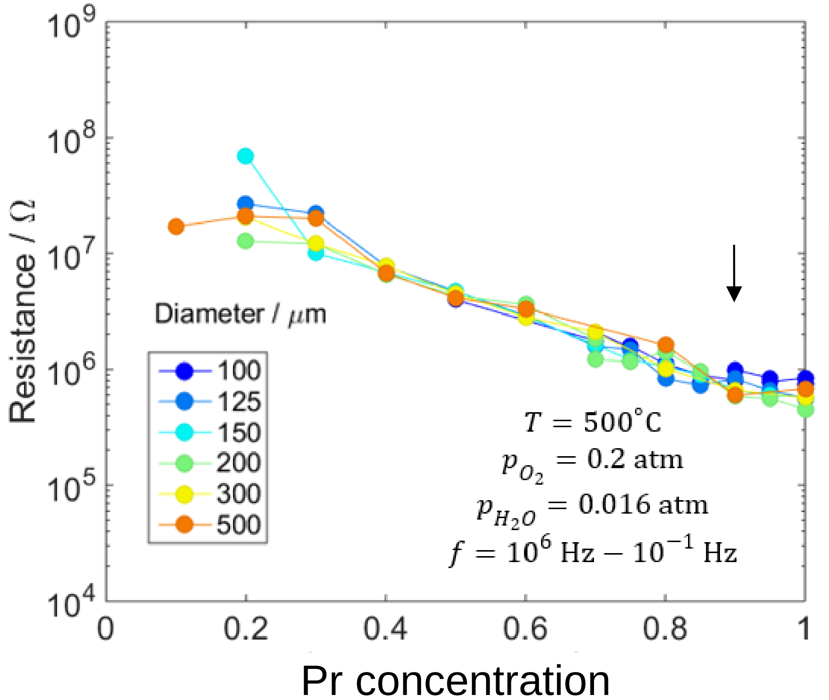
Combinatorial Electrode Development

Cathode: $BaZrYO_3$ - $BaPrYO_3$







Observation: strong composition dependence, slight diameter dependence

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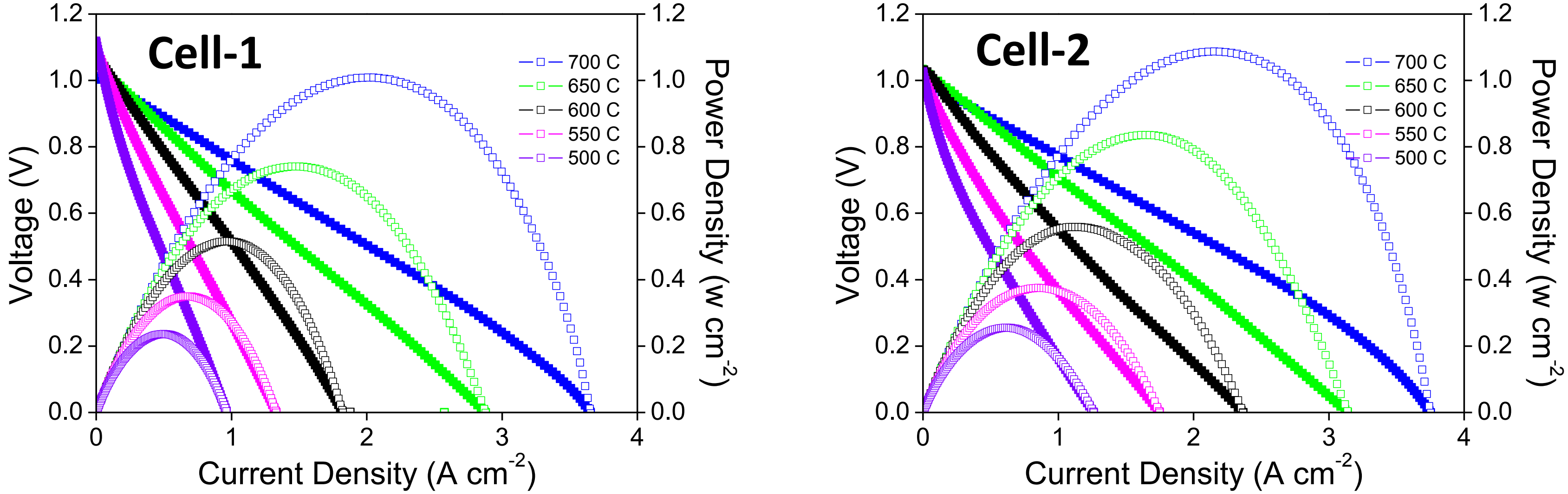
Anode Supported Button Cell Performance in H2



Cathode sintered at 1000 °C

ACIS	ohmic , Ωcm^2		Non-ohmic , Ωcm^2		Peak PD Ωcm^{-2}	
T (^oC)	#1	#2	#1	#2	#1	#2
700	0.179	0.142	0.050	0.056	1.009	1.087
600	0.295	0.213	0.265	0.266	0.516	0.558
500	0.461	0.338	1.420	1.732	0.236	0.255

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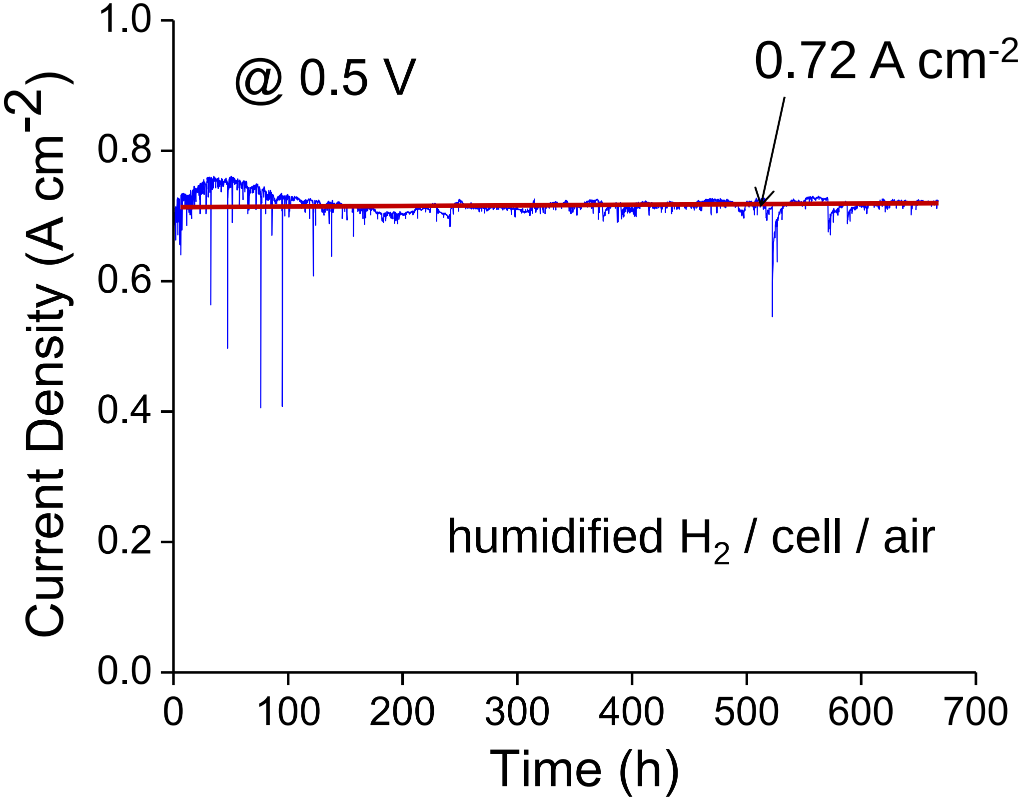
Cell Performance Stability Evaluation



***T* = 550 °C**

- ✓ Test period ≈ 700 h
- ✓ Degradation rate ≈ 0
  $< 2 \times 10^{-3}$ %/h target

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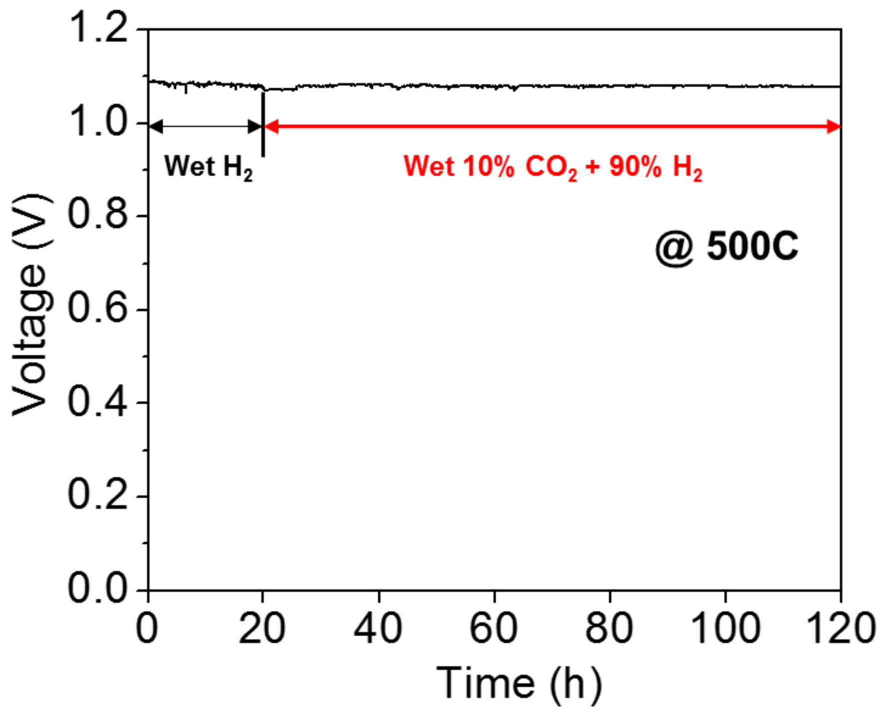
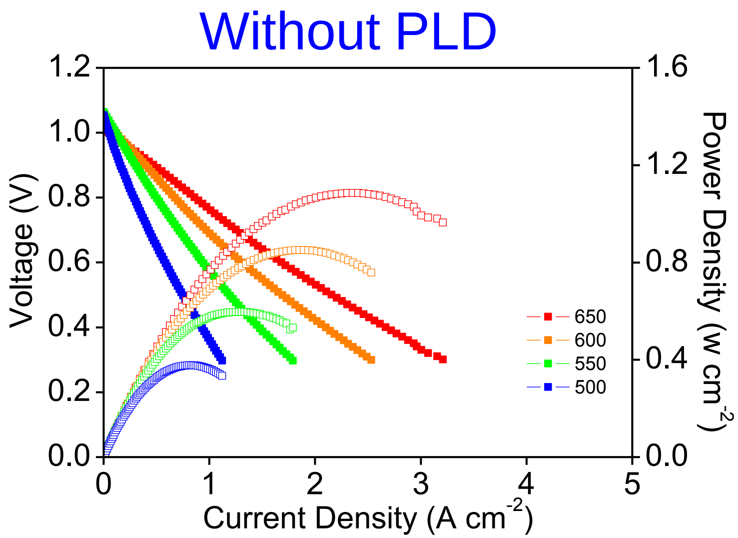
Excellent Stability in CO_2

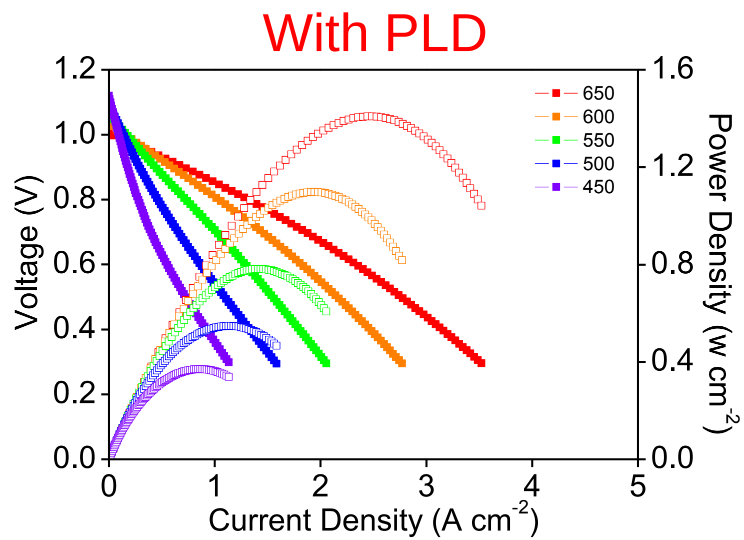
Long-term OCV measurement

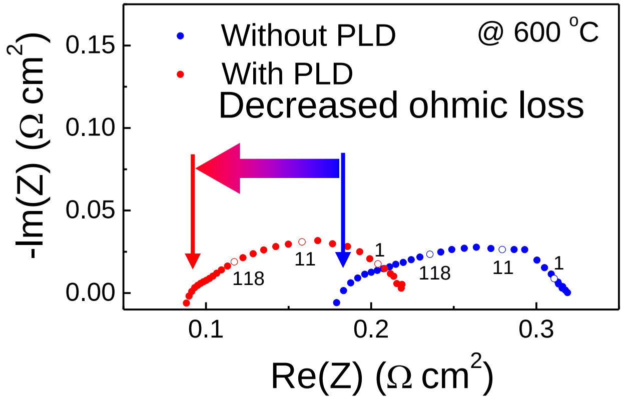


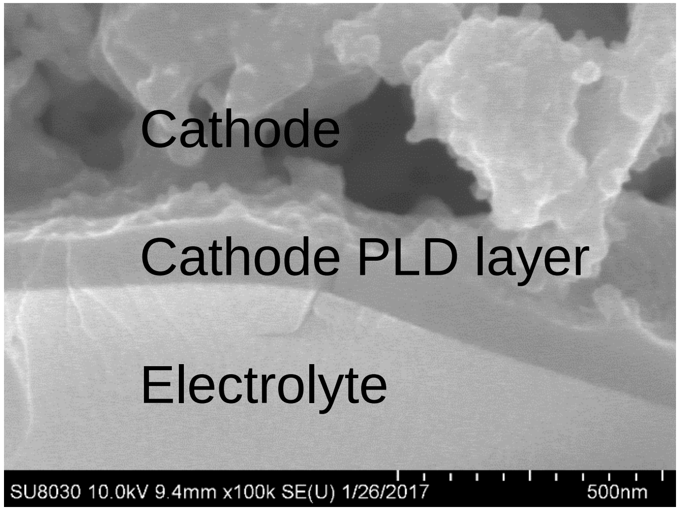
Anode gas: humidified H_2; humidified 90% H_2, 10% CO_2

Further Performance Improvement Demonstrated









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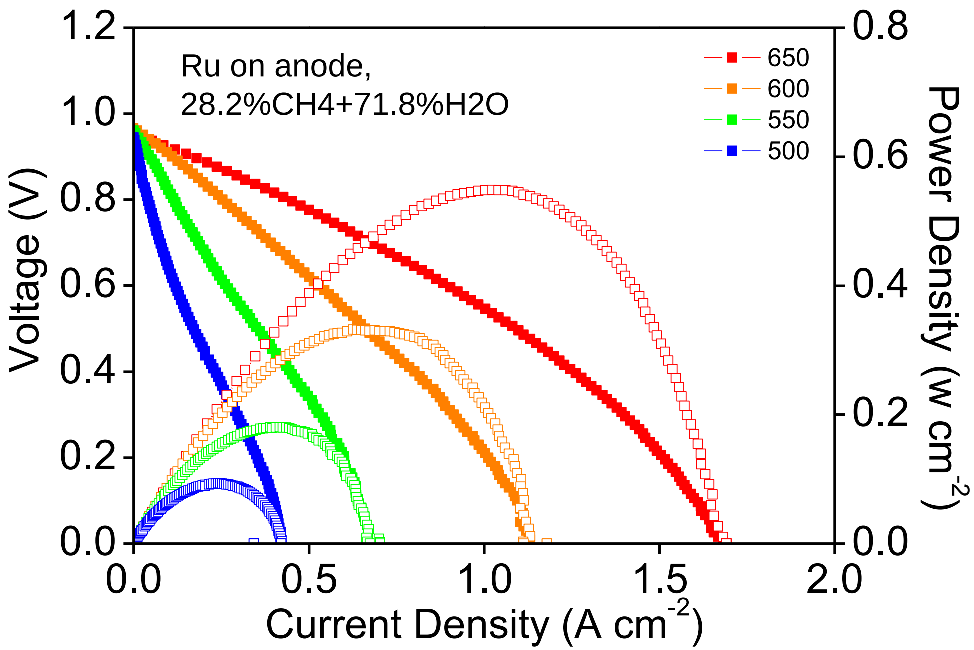
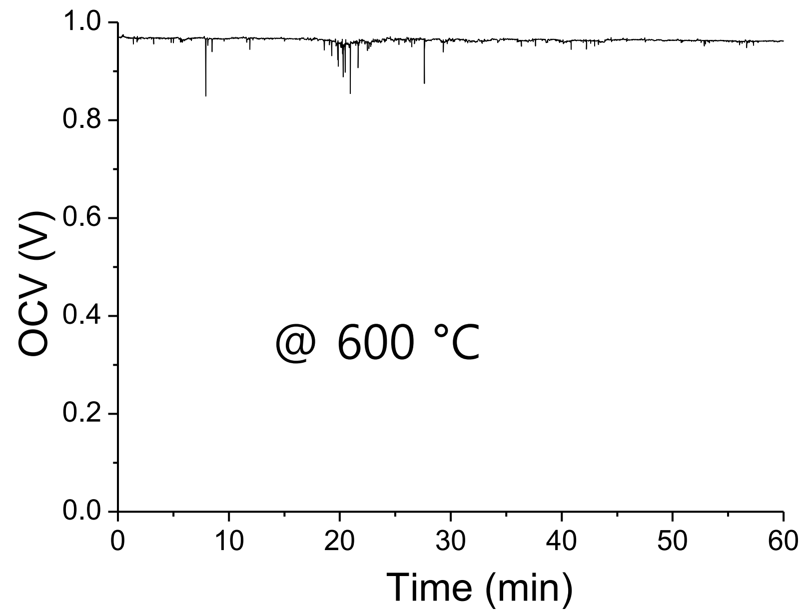
Operation under Methane: 1st Attempt





	Ohmic (Ω cm²)	Non-ohmic (Ω cm²)	Peak power density (W cm⁻²)
650	0.139	0.132	0.548
600	0.197	0.345	0.332
550	0.277	0.992	0.181
500	0.369	2.833	0.094

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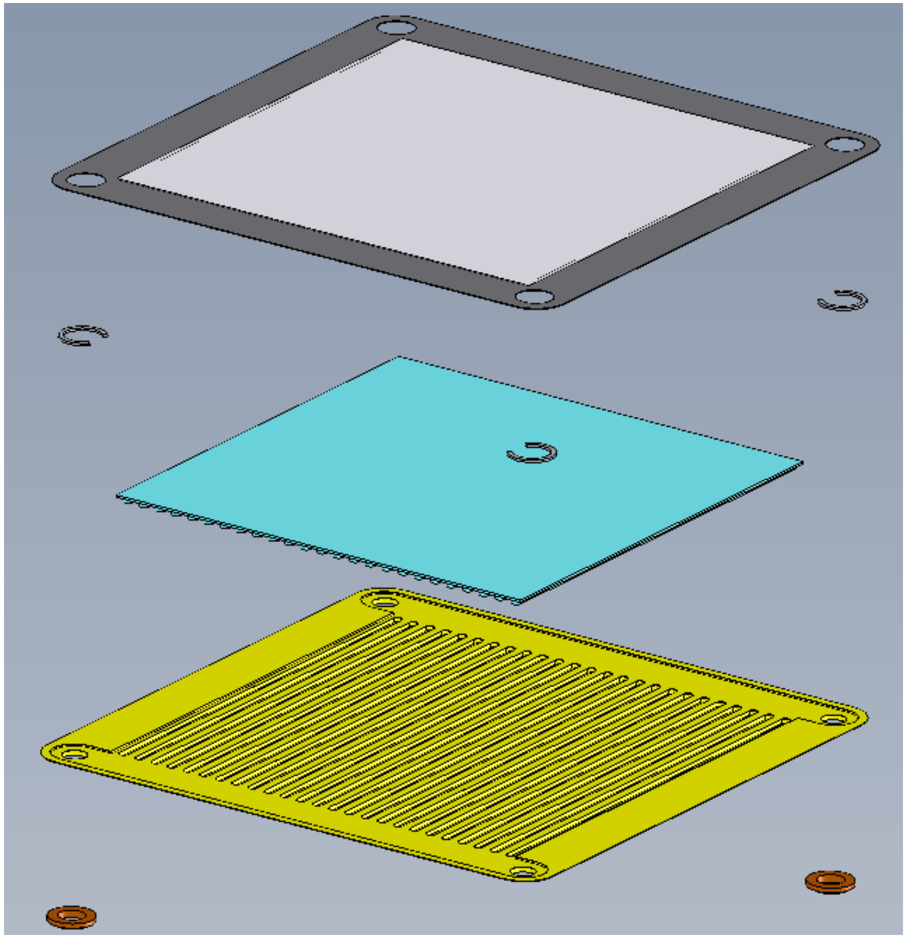
Metal Support Design



(1) Metal Porous Sheet
(substrate for p-SOFC trilayer)

(2) Metal C-Ring Inserts/Orifices
(3 out of 4 visible)

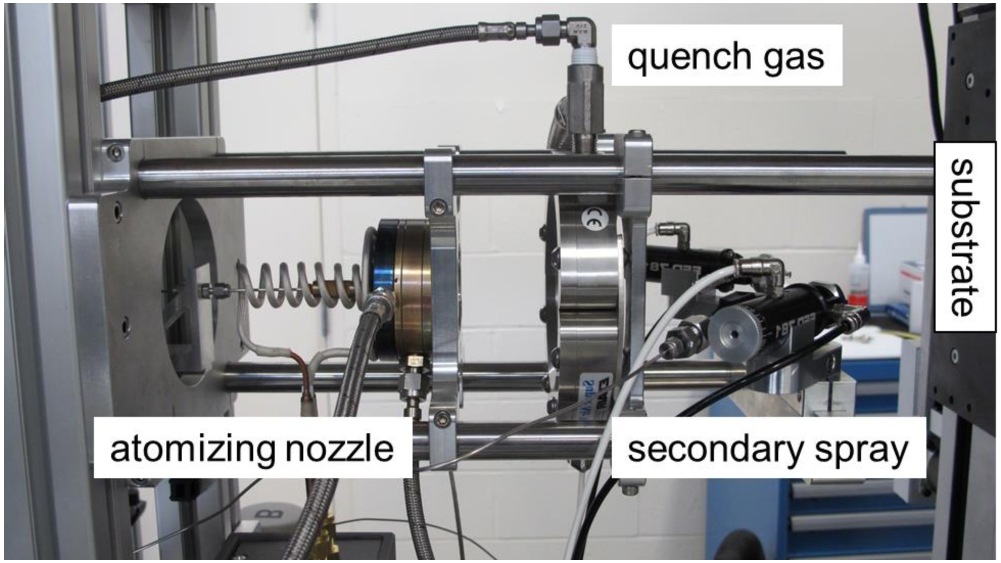
(3) Metal Foam
(substrate for reforming catalyst)

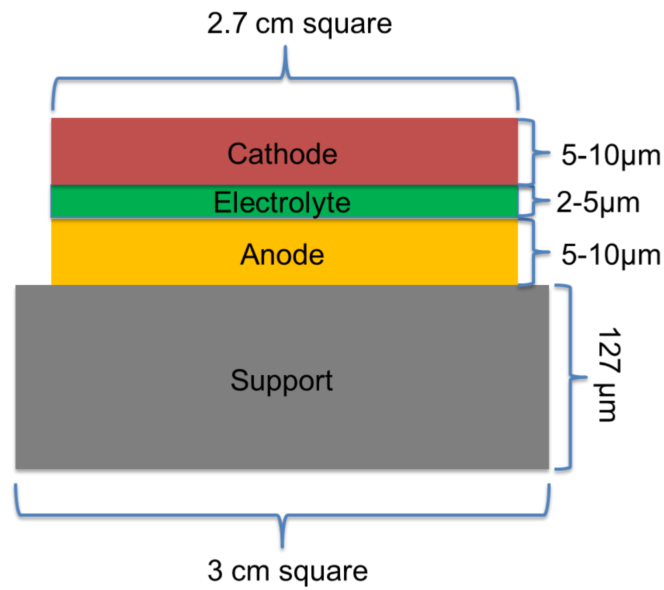
(4) Metal Stamped Dish

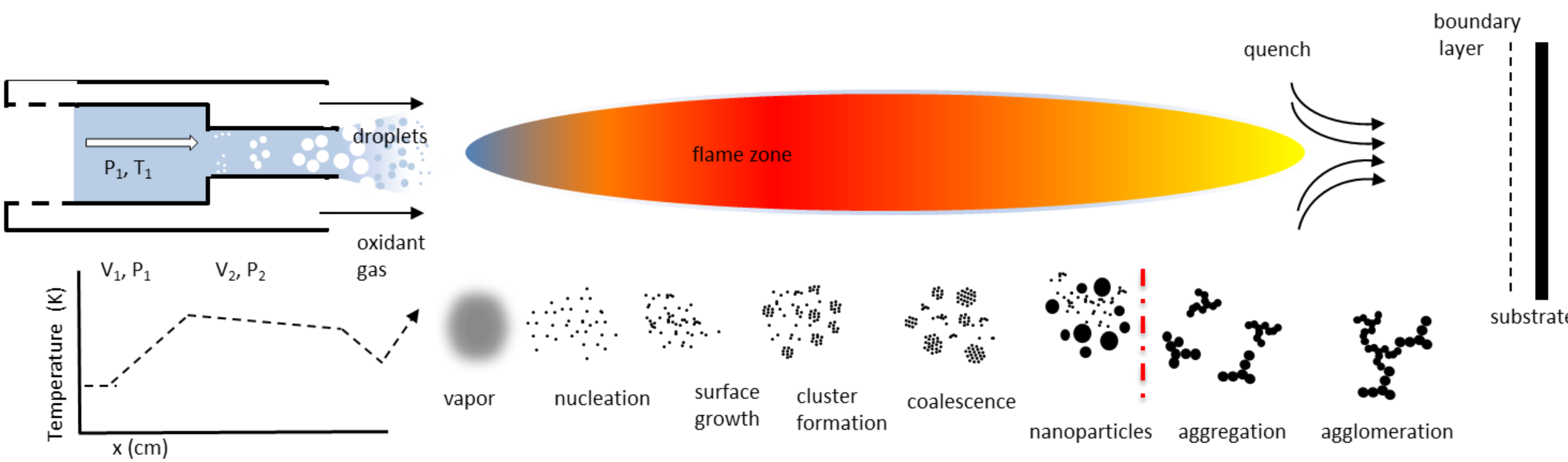
(5) Insulator Couplings
(2 out of 4 visible)

Enabling Fabrication Approach: Reactive Spray Deposition Technology (RSDT)

Cell Manufacturing Process: RSDT







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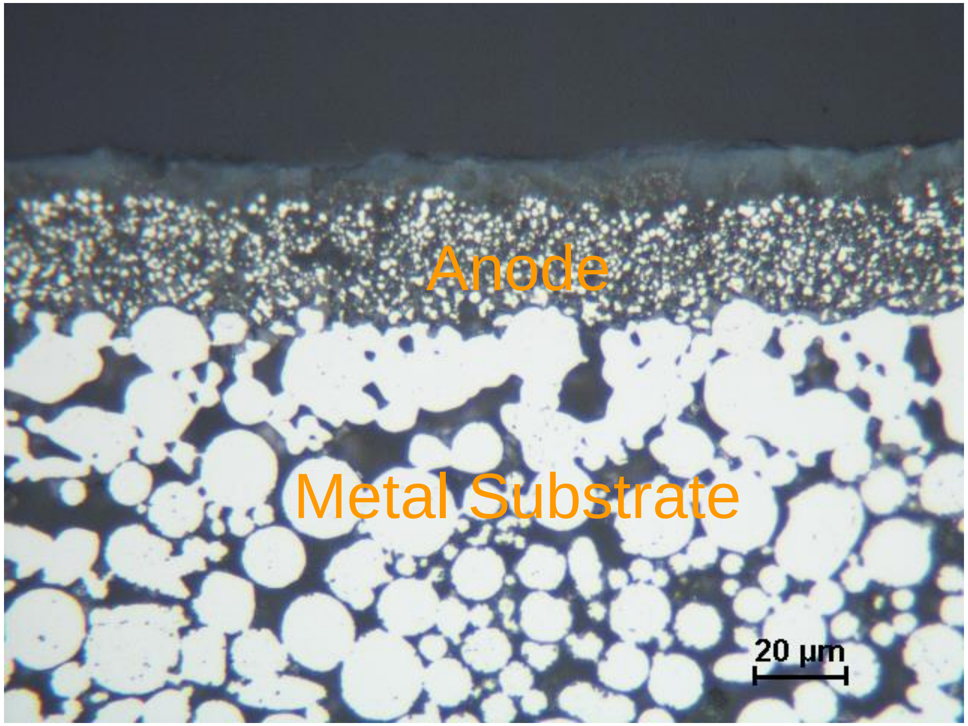
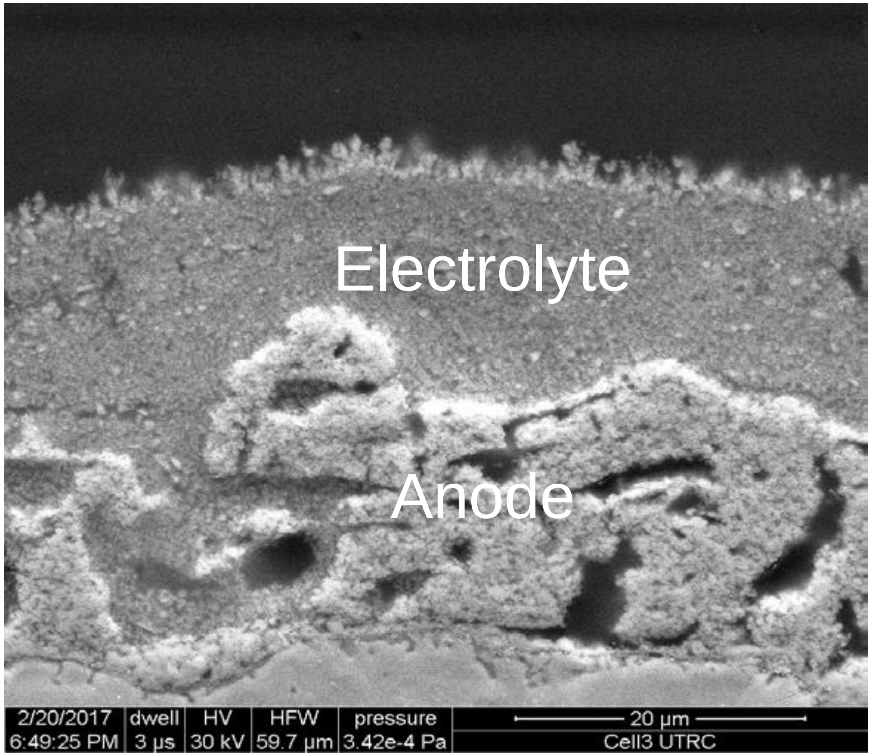
Cell Deposition on Metal Support by RSDT

- Demonstrated thin dense electrolyte (leak rate ~<0.05 ml/min/cm^2 at 1" H_2O)
- Challenges in anode deposition on porous metal:
  - Adherent layer
  - Able to bridge large pores





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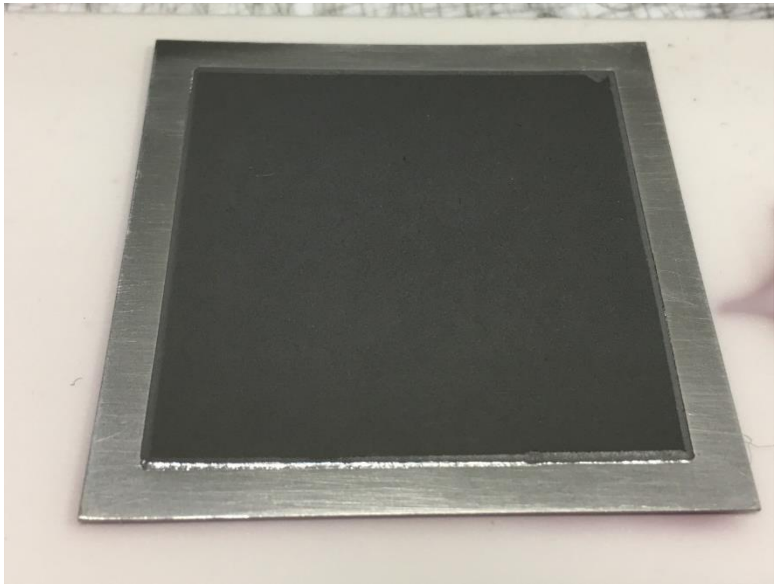
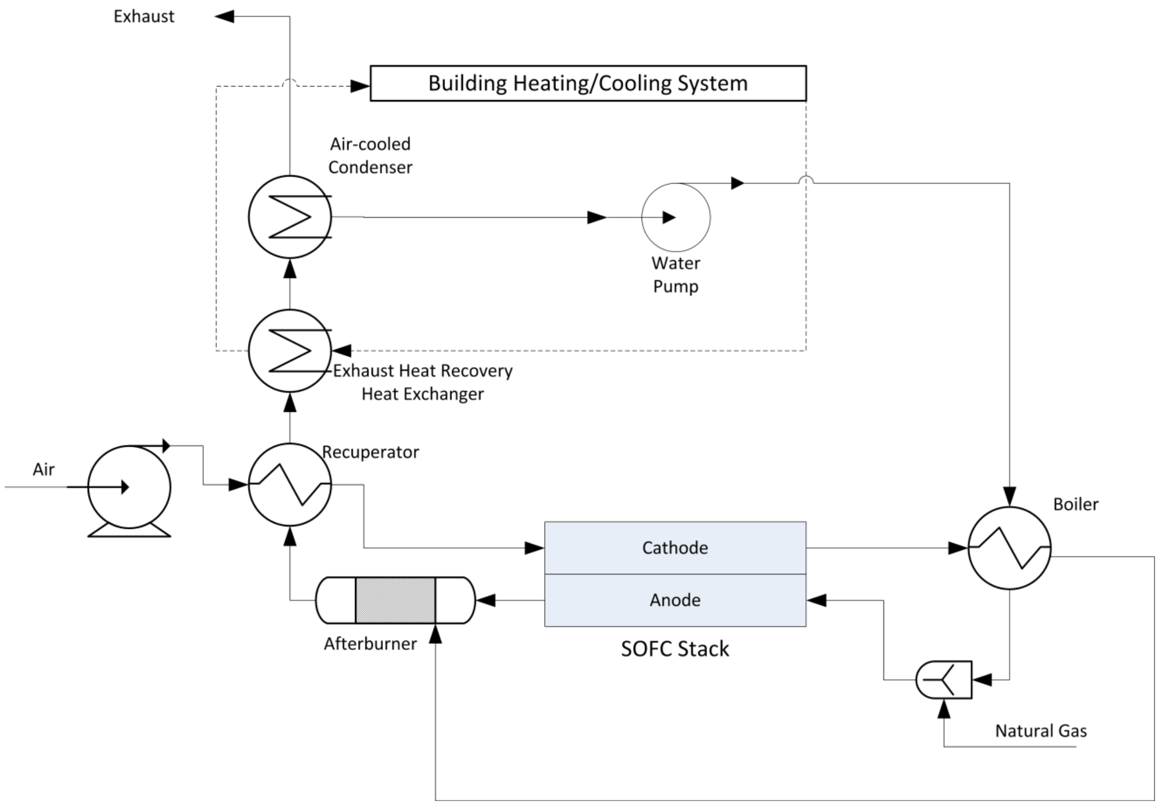
Recent Progress Made in RSDT Full Cell Deposition

5 x5 cm^2 metal supported cell



Technoeconomic Analysis of 5-kWe System

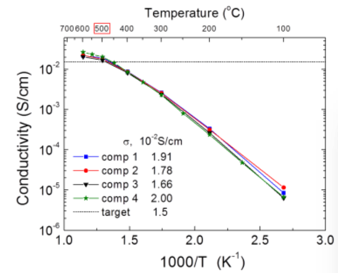


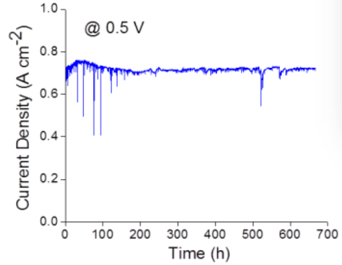
- 8 major system components
- Key operating conditions:
  - Stack mean T = 500 °C; Cell area = 100 cm^2
  - H_2 utilization = 80%; CH_4 reforming conversion = 90%

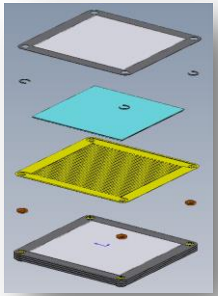
ASR [Ω cm^{-2}]	Stack temp. [°C]	*i* [A cm^{-2}]	Power Density [W cm^{-2}]	Stack cost [$/kWe]	System cost [$/kWe]
1.0	500	0.2	0.17	916	2005
0.5	600	0.2	0.19	764 (-16%)	1323 (-34%)

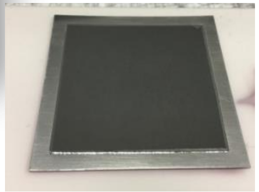
Summary

- Progress
  - Cell materials
  - Stack design
  - RSDT fabrication process









- Next Steps
  - Further improvement of cell deposition
  - Performance demonstration of metal supported cell
  - Continue material development

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Organization	Team Members
Northwestern	Sossina Haile, Sihyuk Choi, Chris Kucharczyk, Daekwang Lim
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United Technologies Research Center	Tianli Zhu, Justin Hawkes, Sean Emerson, Neal Magdefrau, Xian Tang

arpa·e CHANGING WHAT'S POSSIBLE — Grigorii Soloveichik, Scott Litzelman, John Tuttle, John Lemmon

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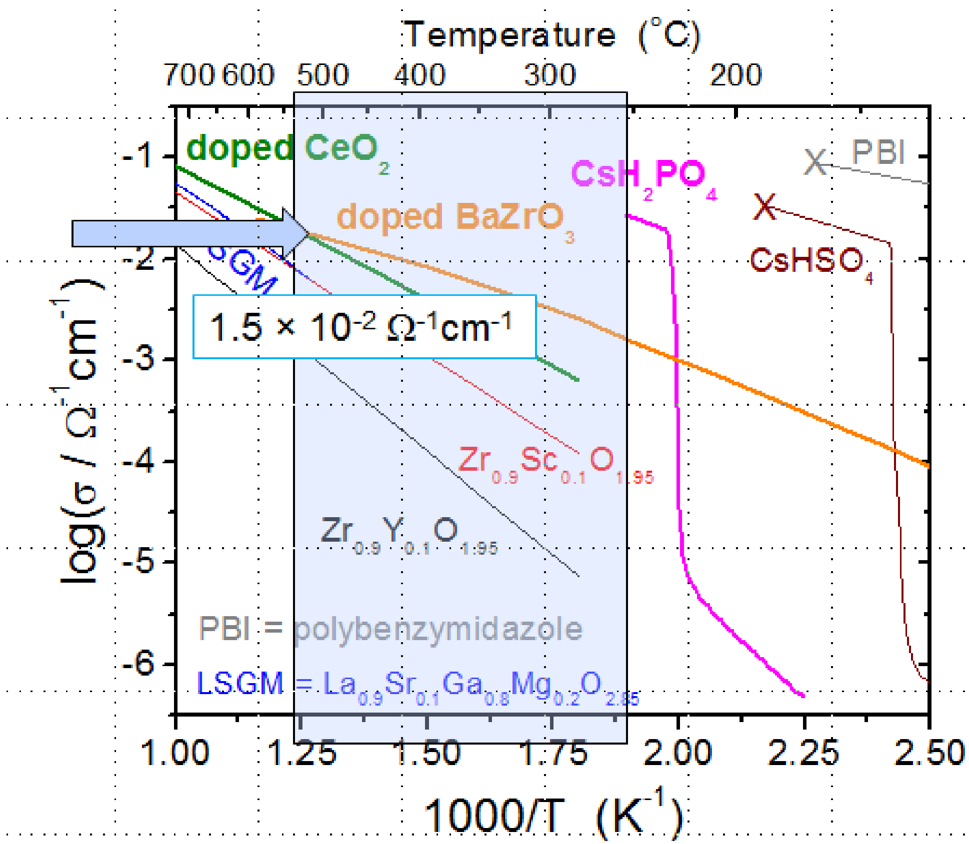
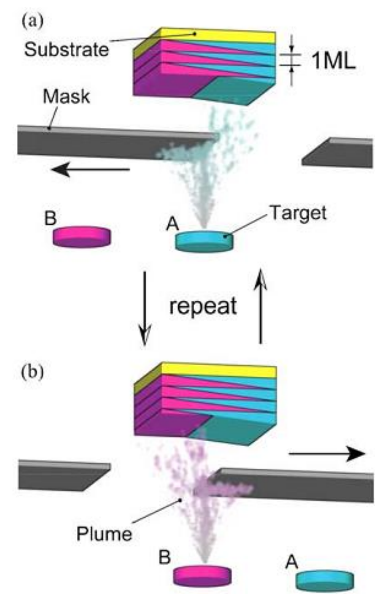
Back Up

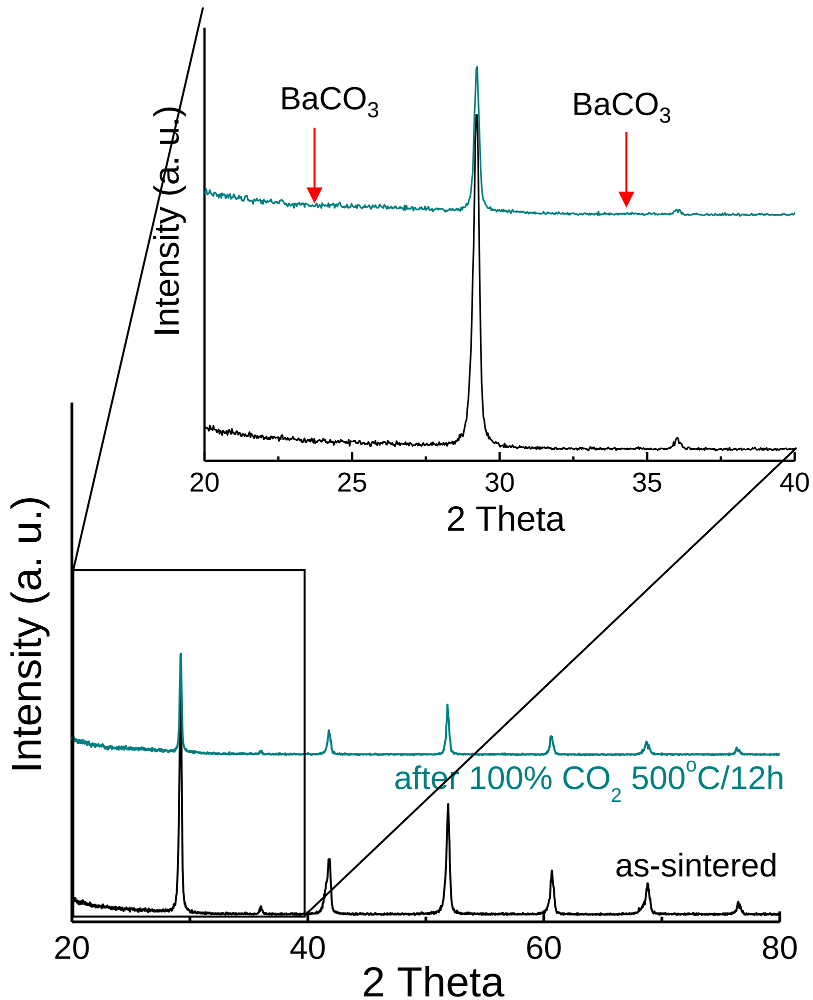
Proton Conducting Oxide

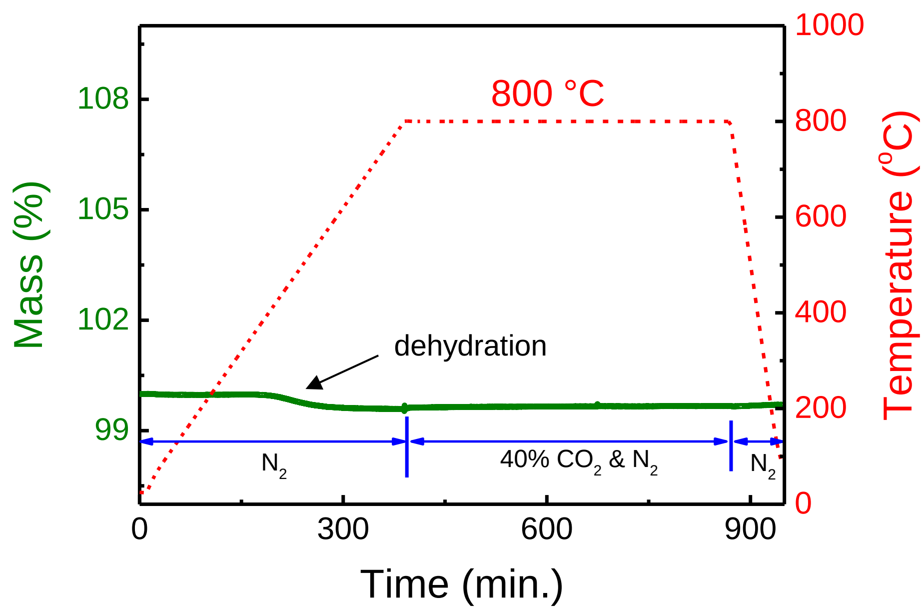
High-Throughput Material Evaluation Approach





CO_2 stability of Gen-2 Electrolyte





- No carbonate detected by diffraction
- No weight gain under flowing CO_2

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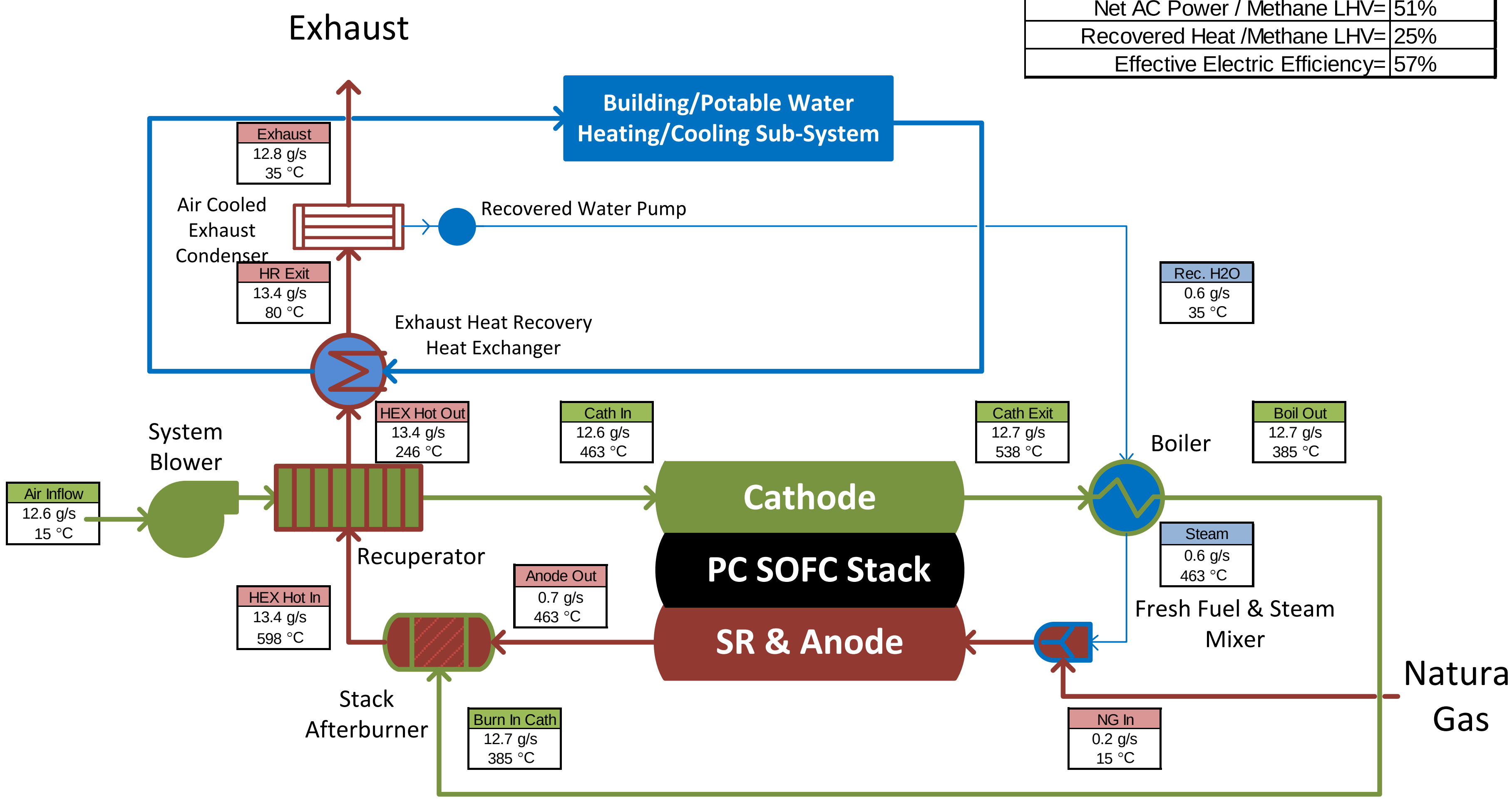
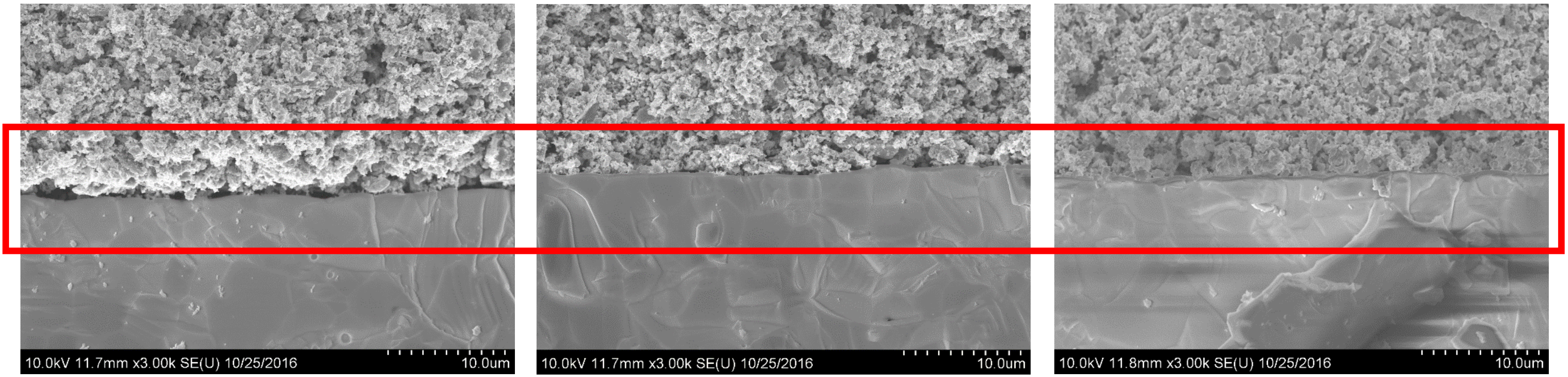
System Concept

5 kW Residential CHP System

Performance Summary	
Net DC Power (W)=	5000
Net AC Power / Methane LHV=	51%
Recovered Heat /Methane LHV=	25%
Effective Electric Efficiency=	57%



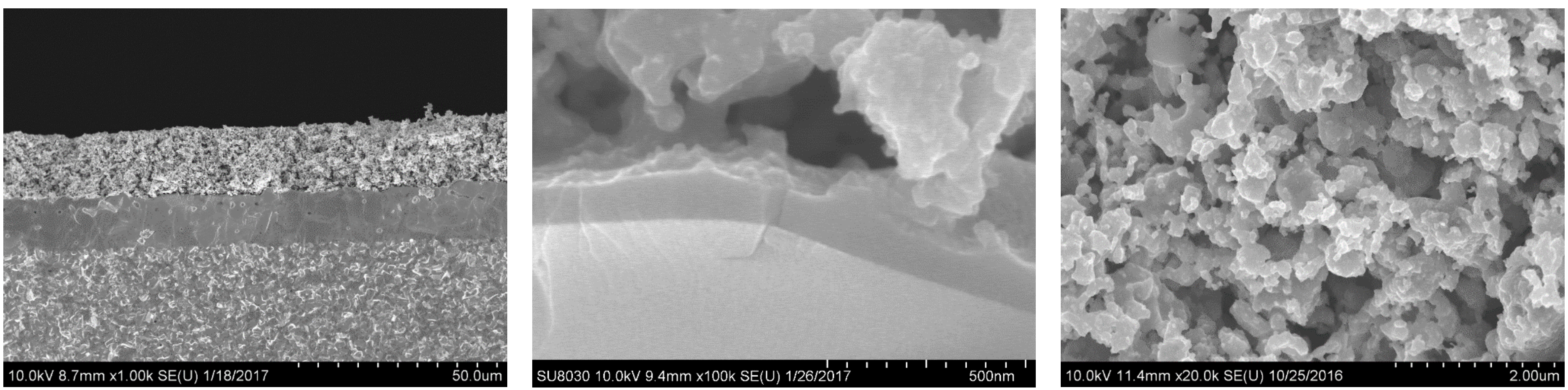
Better Cathode/Electrolyte Interface via PLD Layer



Sintered without PLD 900 °C

950 °C

1000 °C



Sintered at T 950 °C with PLD