The #H2IQ Hour

INCREASE YOUR H2IQ hydrogen.energy.gov

Today's Topic: Spotlight on Los Alamos National Laboratory

November 25, 2024

This presentation is part of the monthly H2IQ hour to highlight hydrogen and fuel cell research, development, and demonstration (RD&D) activities including projects funded by U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE).

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HOUSEKEEPING

The webinar is being recorded and will be available in the **H2IQ Webinar Archives**

Technical Issues:

- If you experience technical issues, please check your audio settings under the “Audio” tab.
- If you continue experiencing issues, direct message the host, Kyle Hlavacek

Questions?

- There will be a Q&A session at the end of the presentation
- To submit a question, please type it into the Q&A box; **do not** add questions to the Chat

This webinar is being recorded.

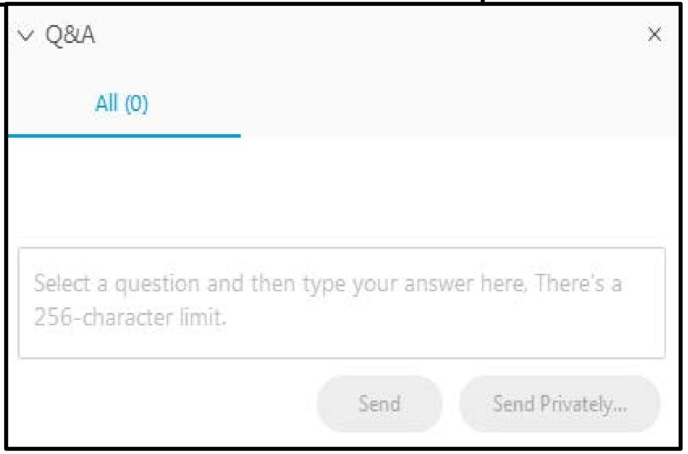
U.S. Department of ENERGY

THE H2IQ HOUR Q&A PROCESS

Please type your questions in the Q&A Box

Open the Q&A panel

1. To open the Q&A panel, click Panel options (Windows) or More options (Mac) ... and select **Q&A**



U.S. Department of ENERGY

Los Alamos
NATIONAL LABORATORY

LANL and Navajo Technical University Collaboration: A Pathway to Participation in Clean Energy Research

H2IQ Hour

Tommy Rockward (trock@lanl.gov)

Nov. 25, 2024

LAUR requested.

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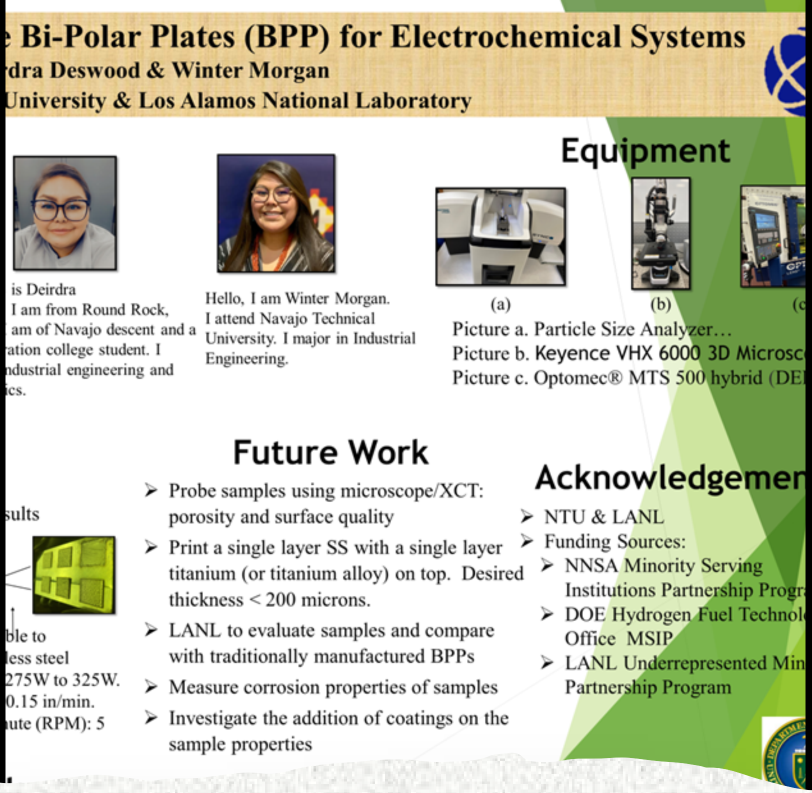


Building on Existing Relationships

LANL and NTU has been working closely to establish synergy between Additive Manufacturing and H_2/FC research.

Professors and students have shown interest in participating in FC-related research and are eager to incorporate their AM capabilities.

Here we present on promising interactions and success stories developed working with Navajo Tech University and some other TCUs.

Our goal is to develop mutually beneficial relationships.

From left, Los Alamos interns with the NTU partnership program are Joel Yazzie, Nylana Murphy, Jasmine Charley and Jonathon Chinana. Los Alamos scientist and program principal investigator Tommy Rockward is at right.

Practical experience with hydrogen fuel cells

From left to right, Los Alamos interns with the NTU partnership program Jonathon Chinana, Joel Yazzie, Nylana Murphy and Jasmine Charley. Los Alamos scientist and program principal investigator Tommy Rockward is at right.

Harnessing potential from untapped talent

Approach:

- Engage in various educational efforts (on-campus research, co-advisement, guest lectures, etc.)
- Complimentary research (AM & FC related)
- Provide long term opportunities

Tribal College Engagement with Hydrogen Technologies:

Support national lab and tribal collaboration on clean H_2 manufacturing RD&D

NAVAJO TECHNICAL UNIVERSITY

Los Alamos
NATIONAL LABORATORY

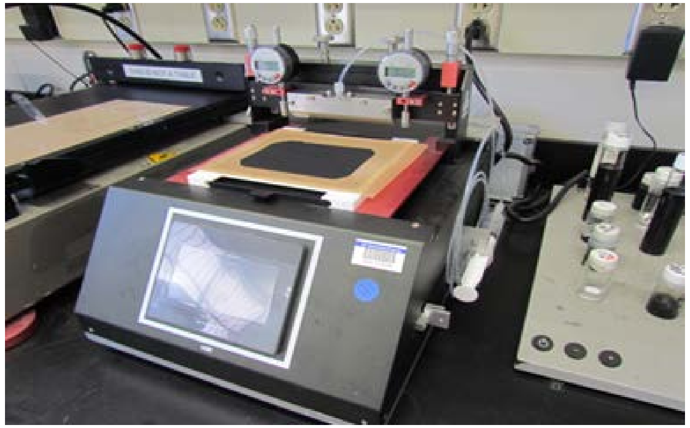
Collaboration with Navajo Technical University supports clean hydrogen careers

Internships offer opportunities in hydrogen and fuel cell research

https://discover.lanl.gov/news/1130-ntu-collaboration/

Native American Scholars make meaningful contributions to the team

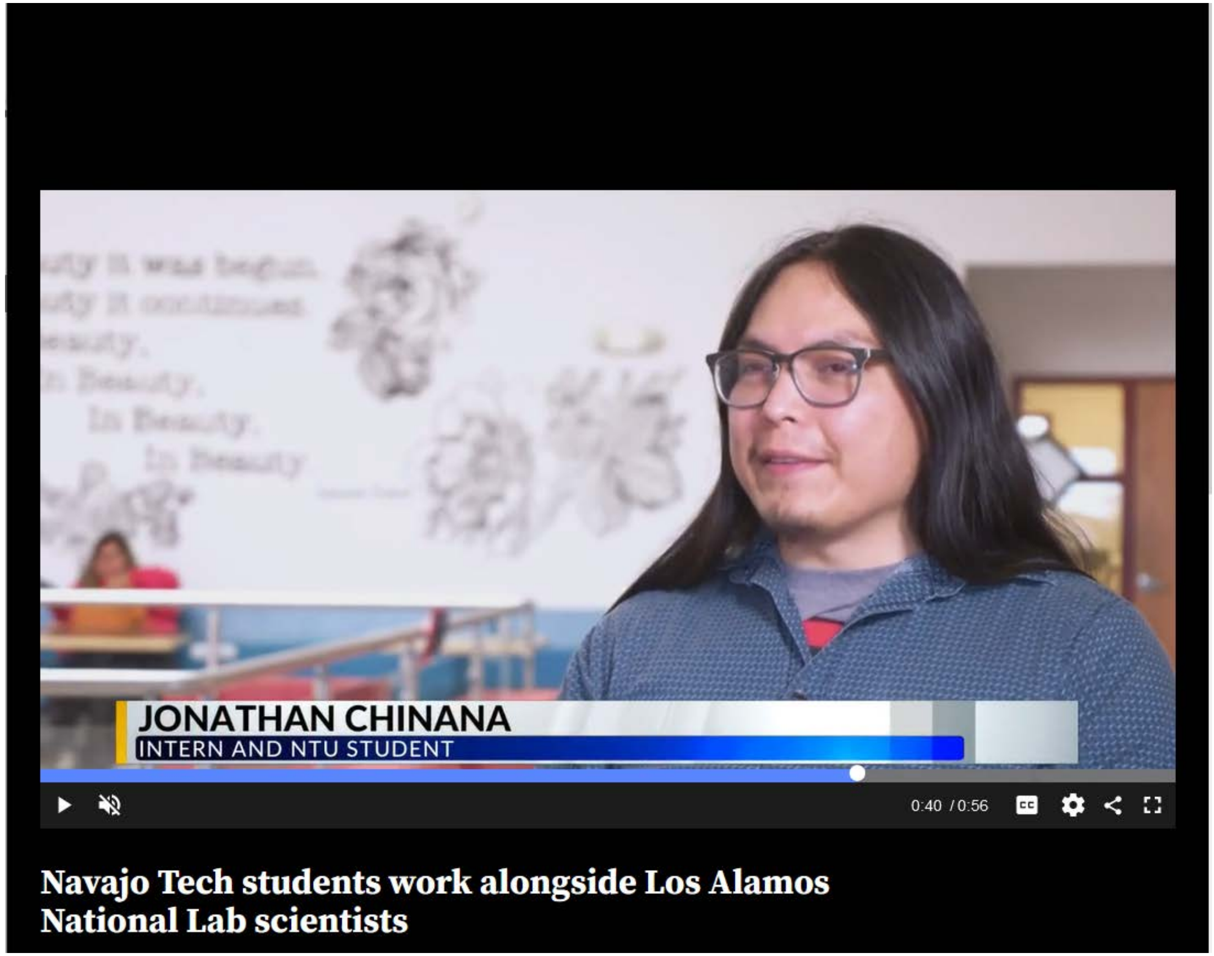
Using AM for Complex Manufacturing Challenges



Modification to Slot Die Coater Electrode Manufacturing Overcomes Challenge https://youtu.be/-RV0UOZu0bk

LANL-NTU Fuel Cell Effort in the News

KRQE News Video: NTU Students work alongside LANL Scientists



https://www.krqe.com/video/navajo-tech-students-work-alongside-los-alamos-national-lab-scientists/9967617/

Jasmine Charley

Jasmine Charley

Jan 2023
Started LANL internship

May 2024
Graduate with A.S. in Mathematics

Dec 2022
Graduated with B.S. in Biology from NTU
Jan 2023
Started A.S in Mathematics

April 2023
Presented first LANL poster at ASU for Graduate Student Conference as an undergrad, inspired me to apply to graduate school

Fall 2024
Started PhD Program in Biomedical Engineering at UNM

Background:

- Year-round internship at LANL
- Research experience in Electrochemistry Analysis
- B.S Biology (NTU)
- A.S Mathematics (NTU, complete in May 2024)
- PhD Research Interests: nano biomaterials, bio nanotechnology, and biomedical analysis

Current Project:

- Obtain training in Electrochemical techniques and the use of characterization techniques such as Inductively coupled plasma mass spectrometry(ICP-MS), Agilent 7500
- Using ICP-MS to analyze solutions that were obtained after corrosion test at LANL, which will indicate the different elements that may cause different results after corrosion test
- I have worked with ICP-MS, Interfacial Contact Resistance (ICR), and Electrochemistry during my internship with LANL

LANL/HFTO/NTU Successes:

Recent NTU graduates enter Purdue University Master’s Program
LANL Staff will Co-Advise Scholars in FC related Research

Nylana Murphy

Navajo woman engineer and recent graduate in Industrial Engineering from Navajo Technical University. Starting in the fall of 2024, she is pursuing a graduate degree in Mechanical Engineering at Purdue University, focusing on additive manufacturing research. **Nylana has also contributed to research at Los Alamos National Laboratory, furthering her expertise in advanced manufacturing.** She plans to work with the Department of Energy (DOE), contributing to advancements in energy and manufacturing technologies.

Winter Morgan

Winter is a passionate Navajo woman engineer who graduated from Navajo Technical University with a degree in Industrial Engineering. She is pursuing a Mechanical Engineering graduate degree at Purdue University, focusing on additive manufacturing and energy-related research. Winter has contributed to research at Los Alamos National Laboratory, enhancing her expertise in advanced manufacturing. **She is dedicated to advancing engineering knowledge and advocates for bringing STEM opportunities to her Indigenous community, aiming to inspire future generations to excel in science and technology.**

Deirdra Deswood

Started Aug. 2021

CENTER FOR ADVANCED MANUFACTURING
Navajo Technical University

Started Intern Process June 2022

Los Alamos NATIONAL LABORATORY

Graduated NTU Spr 2024

Currently LANL Post-Bac

Goal 2025: Purdue University Grad Program with a **LANL-guided Thesis project**

PURDUE UNIVERSITY

Goal 2030: Continue my Career with LANL
Graduate from the PhD program with Purdue University.
Recruit more students from NTU for LANL

B.A.S – Information Technology, Navajo Technical University **(May 2020)**

B.S – Industrial Engineering **(May 2024)**

A.A.S – Mathematics **(May 2024)**

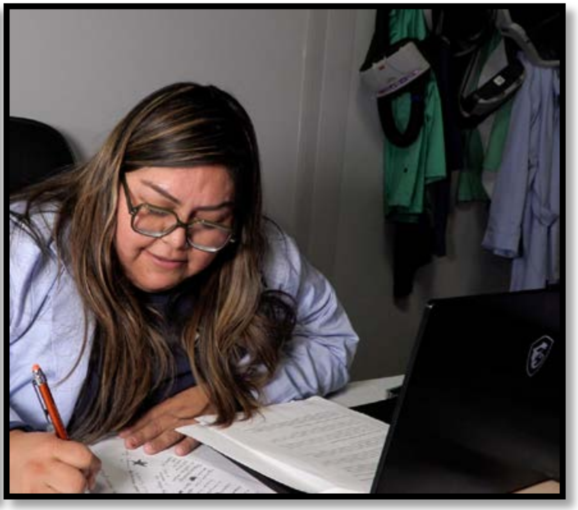
- Undergraduate Student Research Intern beginning Fall 2022

Current Project:

- Investigate the feasibility of using Multi-material AM to fabricate bi-polar (BPP) for fuel cell with improved reliability and performance, quality and repeatability (Using Ti-64 & Ti-64 with Stainless steel 316)

Research Activities include:

- Inductively Coupled Plasma- Mass Spectrometry (ICP-MS),
- Electrochemical Corrosion testing
- Surface Roughness and volume loss using Keyence VK3000 for analysis,
- Porosity Analysis using Vgstudio, and CT Scanning using NSI X300.
- Printing using Optomec MTS 500 Hybrid Direct Energy Deposition Metal AM Machine (repeatability)



Justin Nabaha Gamble

I am from Tuba City Arizona, working on my Bachelors in Environmental Engineering at Navajo Technical University. A fifth-generation cattle rancher, I'm closely connected to the land and want to be able to give back.

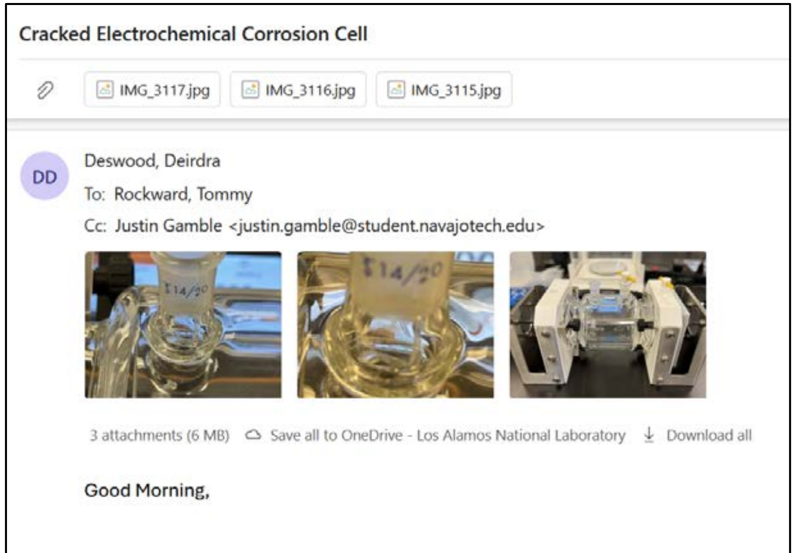
LANL Internship

Technical Skills:

- Agilent ICP-MS
  - MassHunter Program
- PrepFAST
  - Xceleri Data Processing
- Agilent UV-VIS

Project:

BPP Corrosion Studies- Quantitate Ion Leach Rates


Cracked Electrochemical Corrosion Cell

IMG_3117.jpg IMG_3116.jpg IMG_3115.jpg

DD Deswood, Deirdra

To: Rockward, Tommy

Cc: Justin Gamble <justin.gamble@student.navajotech.edu>

3 attachments (6 MB) Save all to OneDrive - Los Alamos National Laboratory Download all

Good Morning,

Los Alamos NATIONAL LABORATORY

Modification of a Slot Die Coater Electrode Manufacturing: Project 1

Ink Parameterization and Surface Treatment

Slot Die Coater

Pristine; $\theta = 139.5°$

30% IPA ; $\theta = 106.3°$

50% IPA; $\theta = 27.5°$

70% IPA; $\theta = 14.9°$

Wettability challenges on GDLs

NAVAJO TECHNICAL UNIVERSITY EST. 1979

Turtle Mountain Community College

Navajo Technical University - Los Alamos Collaboration

Flat Slot Die Coater with modification to allow for pre-treatment to be applied

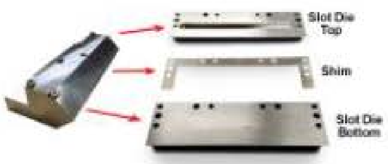
Problem:
Pre-treatment dries too fast causing the substrate to crack before final solution can be administered.

Requirements:

- ❖ Mirror the slot die to create a second die for pre-treatment.
- ❖ Spacer would need to be modified.
- ❖ One blade, two dies.
- ❖ Design a secondary slot die that allows for pre-treatment to be applied within adequate amount of time.

Original slot die only had one orifice to allow for one solution to run at a given time.
The technician would have to connect the pre-treatment, run the program, then disconnect the pre-treatment and change over to the final solution and run the program again.
The time spent on the change over would occasionally cause the substrate to dry out and crack resulting in the technician having to start over.

Slot Die Head Structure



First Solution:
The prototype shown below is only one side because we wanted to run a test before printing the rest of the prototype. The Prototype did fail because water was Not able to pass through the channel. The extruded hole is being reposition at an Angle.

Second solution:
Create a slot die with same dimensions as the original.
The die would attach to the original and cut down on the change over time.
Separate channel for pre-treatment to.

Joel Yazzie
B.S Mechanical Engineering

Wynona Wilson
B.S Mechanical Engineering

Achievements:

Having two solutions allows for more than one option.

Being able to show our creativity and still have a final part.

Los Alamos

CENTER FOR ADVANCED MANUFACTURING

Outreach Activities: Recruiting Tool

STEM day

May 20th, 2024

Calling all future scientists, engineers, and innovators!

- Learn about exciting careers in STEM
- Meet LANL recruiters and scientists
- Explore the possibilities at LANL

Energy Cycle Demonstration: Solar to Electrolysis to Fuel Cell Powered

Come and join us!

3:00 PM – 4:00 PM

Los Alamos National Laboratory internship opportunity presentation

Nebraska Indian Community College

ASPIRE Visit 11/13/24

Tours

Personnel	Facility	Total Duration
Sundar Kunwar	CINT	~ 40 min
Mike McBride	Sigma	~ 1 hour
Sven Vogel	LANSCE	~ 1.5 hour
Eric Davis & Gonzalo	Acoustics	~ 30 min
Christian, Rigo, & Tommy	Fuel Cell	~ 30 min

Tentative Agenda

United Tribes Technical College

Turtle Mountain Community College

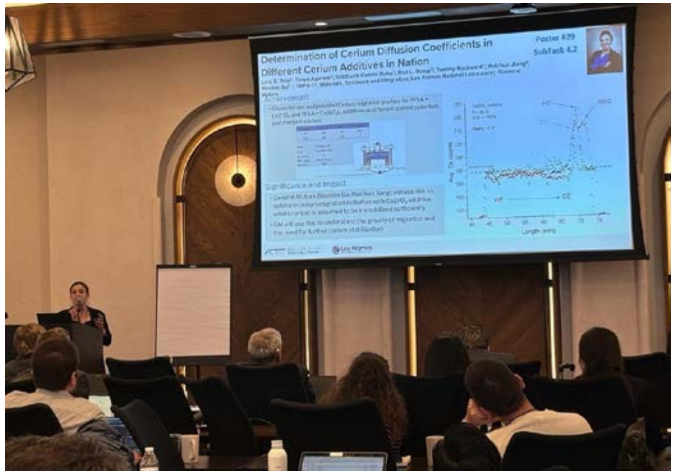
9:00 AM – 9:30 AM	Meet at SM-40 for badging, introductions, coffee/snacks?, divide into 2 groups
9:30 AM – 10:00 AM	**Group 1:** Fuel Cell tour **Group 2:** Acoustics tour
10:00 AM – 10:30 AM	**Group 1:** Acoustics tour **Group 2:** Fuel Cell tour
10:30 AM – 10:45 AM	Travel to CINT
10:45 AM – 11:30 AM	**Group 1** and **Group 2** split and simultaneously
11:30 AM – 11:45 AM	Travel to lunch destinat
11:45 AM – 1:30 PM	Working lunch ?
1:30 PM – 1:45 PM	Travel to SIGMA
1:45 PM – 2:45 PM	**Group 1** and simultan
2:45 PM – 3:00 PM	Trave
3:00 PM – 4:30 PM	G
4:30 PM – 4:45 PM	

Lyra Troy- Ambassador & Mentor

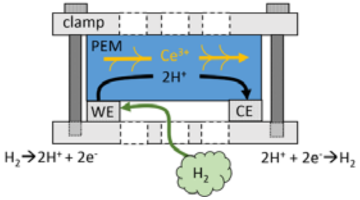
Research Topics

- Characterize Ce^{3+} movement in novel membranes using controlled test cell and XRF imaging techniques
- Corrosion of Bi-Polar Plates
- Testing Novel 3-Membrane Configurations for Improved Understanding and Durability in FCs
- Fusion-related Studies

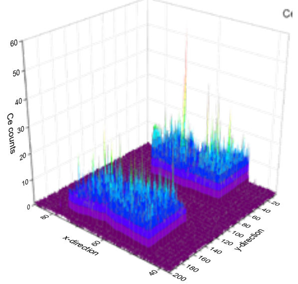
Lyra Troy
M.S. Chemical Engineering
Chiricahua Apache

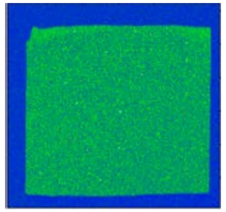


Membrane samples in test cell



XRF Mapping

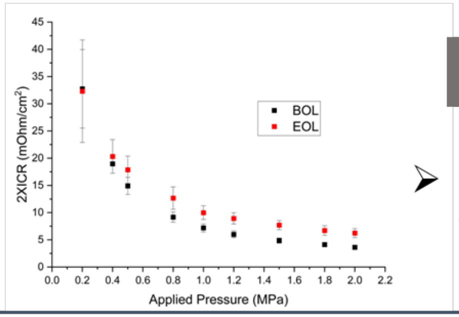


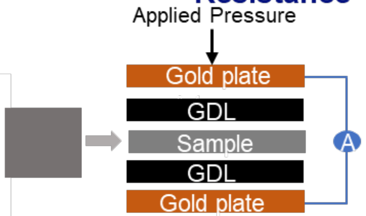


Corrosion of Bi-Polar Plates

- Engineered a custom ICR template design for high resolution data

Interfacial Contact Resistance





- Unique design allows for data accuracy and reproducibility

Highlights

- ✓ MSIPP Post Master's Researcher
- ✓ Characterized cerium mobility in membranes with new additives
- ✓ Provided General Motors with experimental data needed for modeling and membrane lifetime parameters

May 2020	*Dec. 2022*	*Oct. 2022-Present*	*LANL Job Interviews*	*Q-7*
B.S. Chemical Engineering B.S. Mathematics **University of Arizona**	M.S. Chemical Engineering **University of Arizona**	Post Master's Researcher **Los Alamos National Laboratory**	AAMP-5 & Q-7	

Acknowledgements

- Hydrogen Fuel Cell Technologies Office
- Underrepresented Minority Program (formerly African American Partnership Program)-LANL's Director's Office
- NNSA Minority Serving Institution Partnership Program

L’Innovator 2.0 Program: Novel Fuel Cell Catalysts and Electrode Structures

Jacob S. Spendelow

November 25, 2024

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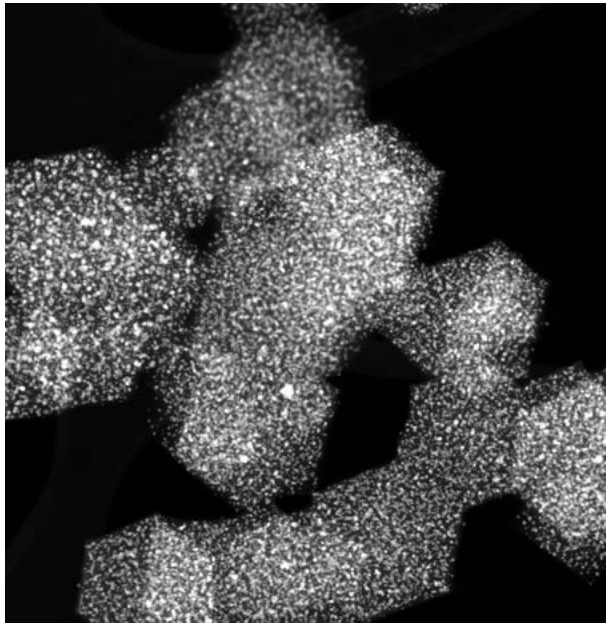
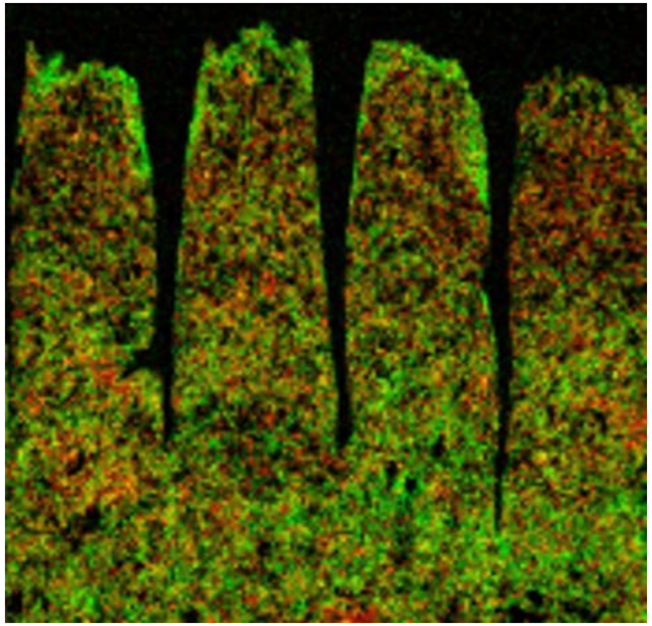
L'Innovator 2.0

L'Innovator 2.0 provides an opportunity to partner with LANL on commercializing next generation fuel cell catalysts and electrode structures

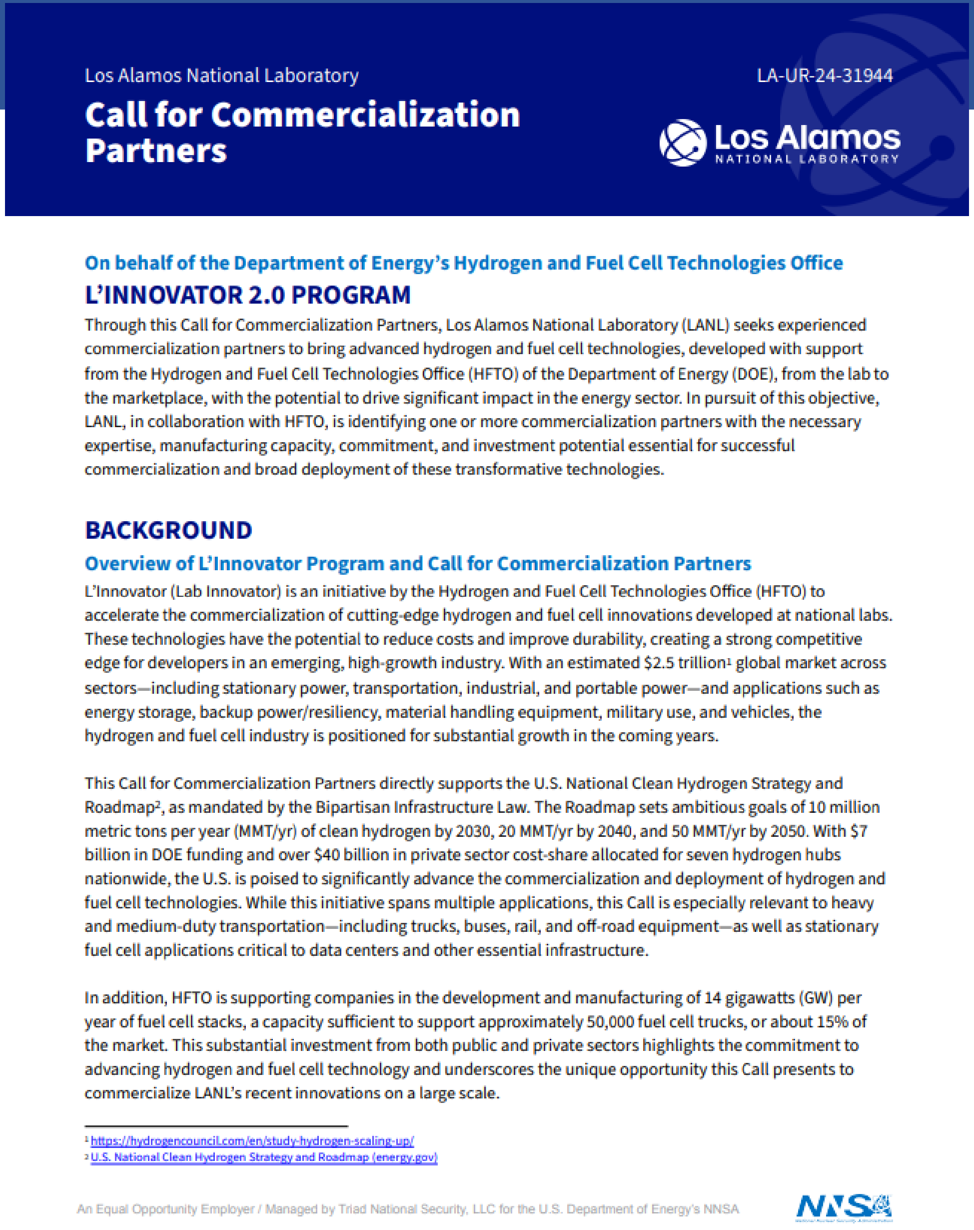
Catalysts



Electrodes



L'Innovator 2.0 call posted at: https://www.lanl.gov/engage/collaboration/feynman-center/



Los Alamos National Laboratory

LA-UR-24-31944

Call for Commercialization Partners

Los Alamos NATIONAL LABORATORY

On behalf of the Department of Energy's Hydrogen and Fuel Cell Technologies Office

L'INNOVATOR 2.0 PROGRAM

Through this Call for Commercialization Partners, Los Alamos National Laboratory (LANL) seeks experienced commercialization partners to bring advanced hydrogen and fuel cell technologies, developed with support from the Hydrogen and Fuel Cell Technologies Office (HFTO) of the Department of Energy (DOE), from the lab to the marketplace, with the potential to drive significant impact in the energy sector. In pursuit of this objective, LANL, in collaboration with HFTO, is identifying one or more commercialization partners with the necessary expertise, manufacturing capacity, commitment, and investment potential essential for successful commercialization and broad deployment of these transformative technologies.

BACKGROUND

Overview of L'Innovator Program and Call for Commercialization Partners

L'Innovator (Lab Innovator) is an initiative by the Hydrogen and Fuel Cell Technologies Office (HFTO) to accelerate the commercialization of cutting-edge hydrogen and fuel cell innovations developed at national labs. These technologies have the potential to reduce costs and improve durability, creating a strong competitive edge for developers in an emerging, high-growth industry. With an estimated $2.5 trillion[1] global market across sectors—including stationary power, transportation, industrial, and portable power—and applications such as energy storage, backup power/resiliency, material handling equipment, military use, and vehicles, the hydrogen and fuel cell industry is positioned for substantial growth in the coming years.

This Call for Commercialization Partners directly supports the U.S. National Clean Hydrogen Strategy and Roadmap[2], as mandated by the Bipartisan Infrastructure Law. The Roadmap sets ambitious goals of 10 million metric tons per year (MMT/yr) of clean hydrogen by 2030, 20 MMT/yr by 2040, and 50 MMT/yr by 2050. With $7 billion in DOE funding and over $40 billion in private sector cost-share allocated for seven hydrogen hubs nationwide, the U.S. is poised to significantly advance the commercialization and deployment of hydrogen and fuel cell technologies. While this initiative spans multiple applications, this Call is especially relevant to heavy and medium-duty transportation—including trucks, buses, rail, and off-road equipment—as well as stationary fuel cell applications critical to data centers and other essential infrastructure.

In addition, HFTO is supporting companies in the development and manufacturing of 14 gigawatts (GW) per year of fuel cell stacks, a capacity sufficient to support approximately 50,000 fuel cell trucks, or about 15% of the market. This substantial investment from both public and private sectors highlights the commitment to advancing hydrogen and fuel cell technology and underscores the unique opportunity this Call presents to commercialize LANL's recent innovations on a large scale.

[1] https://hydrogencouncil.com/en/study-hydrogen-scaling-up/
[2] U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov)

L’Innovator 2.0

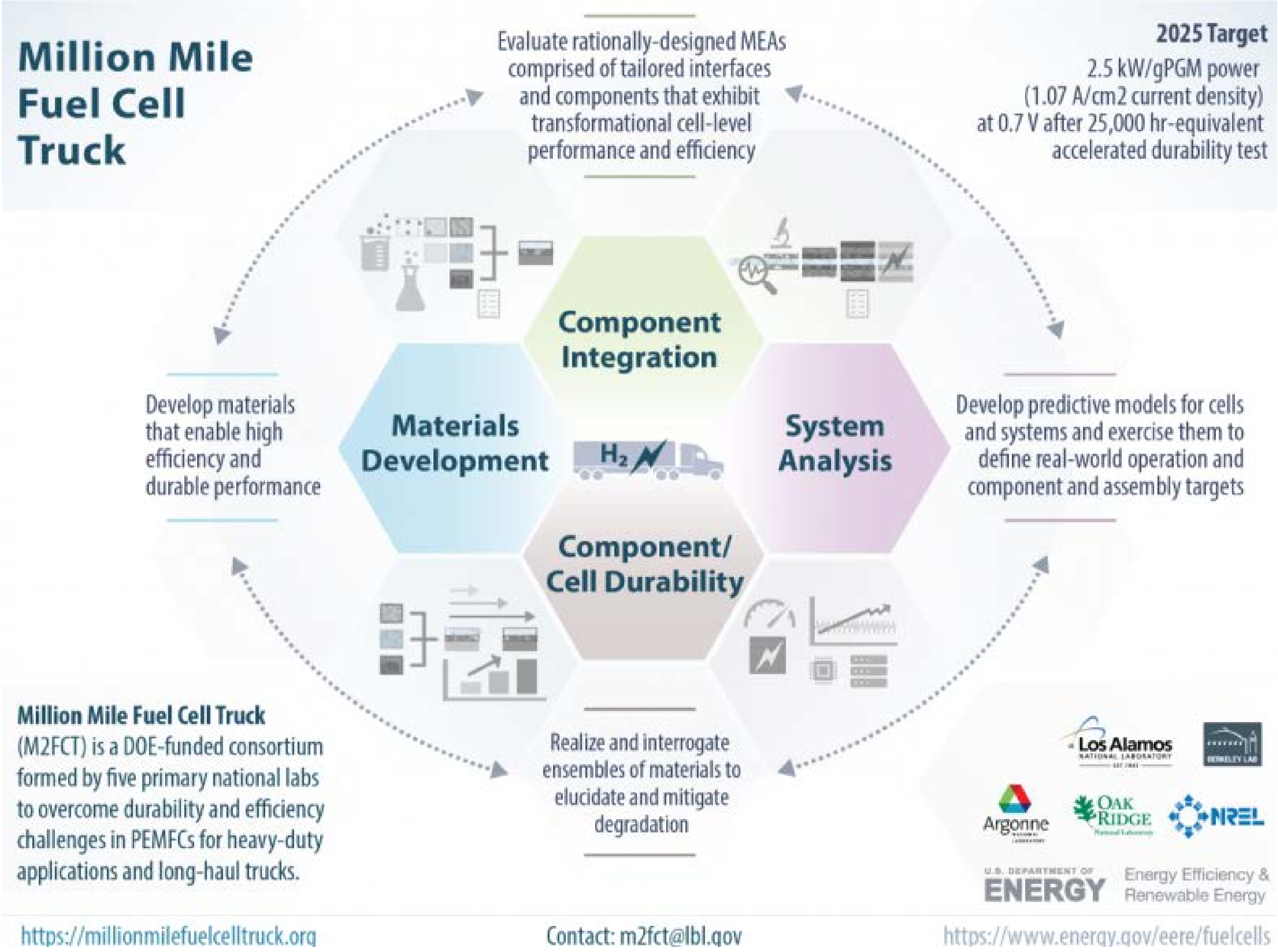
L’Innovator 2.0 presents a unique opportunity for prospective manufacturing companies and investors to:

- Access LANL catalyst and electrode IP via a streamlined process
- Access support from LANL in the development and demonstration of a minimum viable product, co-funded by HFTO

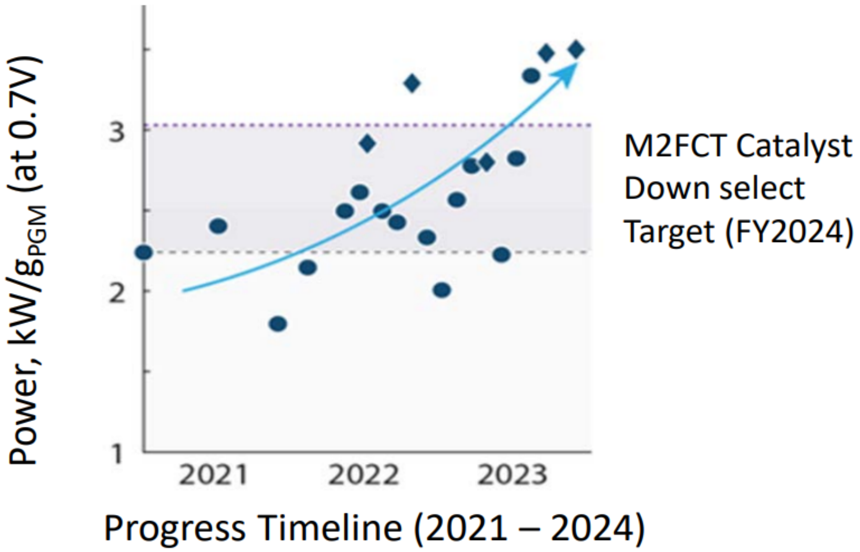
IP included in L’Innovator 2.0:

- S133679 (pending) “Ionomer Membranes For Fuel Cells And Related Devices.” Mukundan, Rangachary (Mukund), Borup, Rodney L (Rod), Spendelow, Jacob Schatz, Komini Babu, Siddharth.
- S133689, US Patent 12009525B2, “Coaxial Nanowire Electrode.” Siddharth Komini Babu, Jacob Schatz Spendelow, Rangachary Mukundan.
- S167564 (pending) “Groovy Fuel Cell Electrodes for Enhanced Performance.” Mukundan, Rangachary (Mukund), Borup, Rodney L (Rod), Spendelow, Jacob Schatz, Lee, Chung Hyuk, Komini Babu, Siddharth.
- S167605 (pending) “Electrodes Based on Catalytic Nanofilms.” Spendelow, Jacob Schatz, Liyanage, Wipula Priya Rasika, Yang, Gaoqiang, Komini Babu, Siddharth.
- S167606 (pending) “Robust Structured Electrolyte-Electrode Interface for Electrochemical Devices.” Yang, Gaoqiang, Martinez, Ulises, Lee, Chung Hyuk, Spendelow, Jacob Schatz, Komini Babu, Siddharth.
- S167614 (pending) “Intermetallic Catalysts With High Performance and Durability.” Wang, Chenyu, Spendelow, Jacob Schatz, Pan, Yung-Tin.
- S167690 (pending) “Porous Catalyst Supports with Differentiated Transport Channels.” Spendelow, Jacob Schatz, Wang, Xiaojing, Chen, Kate, Li, Kui.

Million Mile Fuel Cell Truck Consortium (M2FCT)



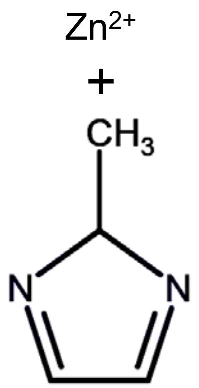
Progress in catalyst and electrode design drives continuous progress in performance and durability



Carbonized MOF Catalyst Supports

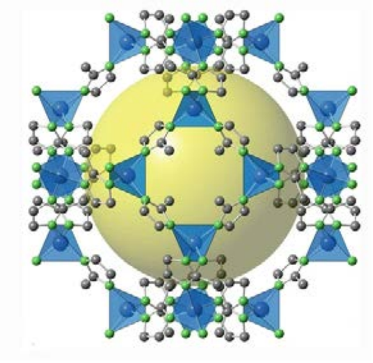
Metal organic frameworks (MOFs), including ZIF-8, provide flexible precursors for tunable supports

Low-cost Precursors



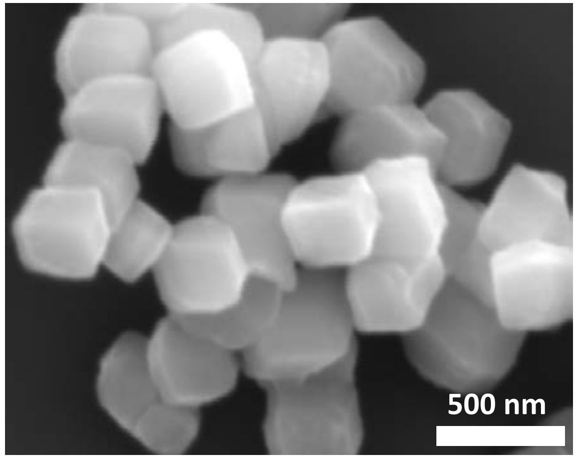
ZIF-8 Nucleation

ZIF-8 Nuclei



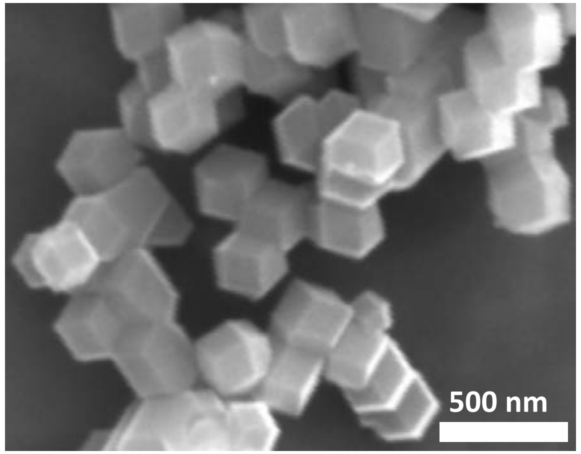
Crystal Self-assembly

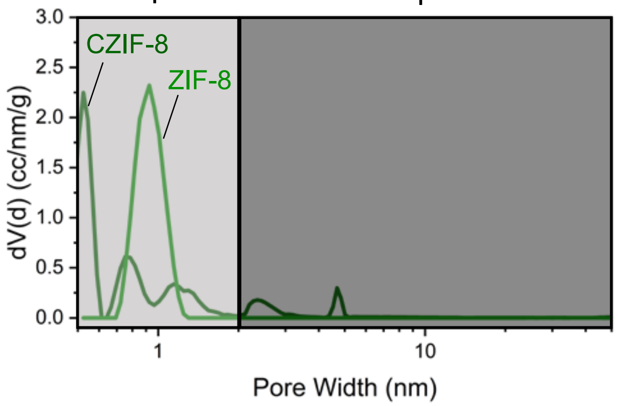
ZIF-8 Crystals

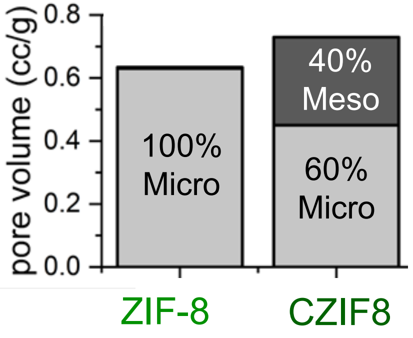


Carbonization at 1100 °C

Carbonized ZIF-8 (CZIF8)



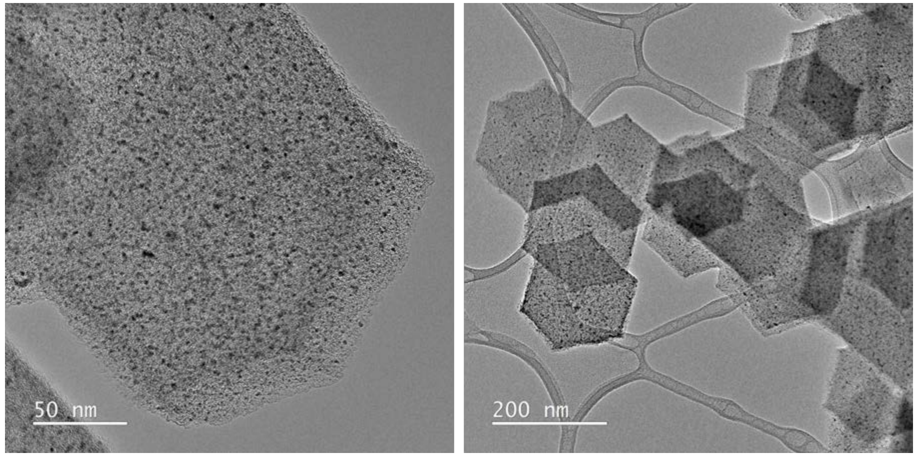


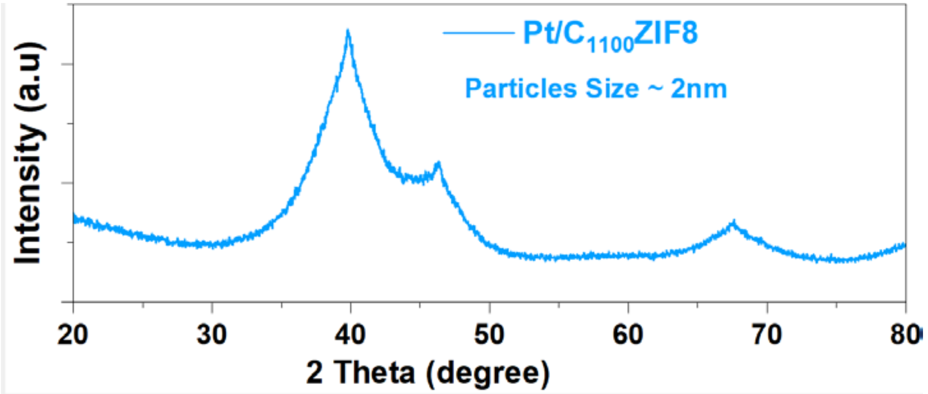


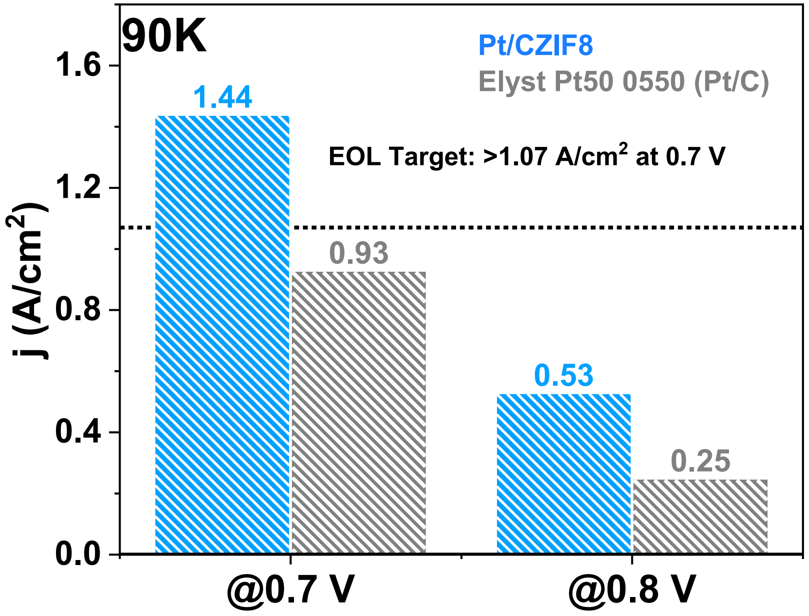
CZIF8 has excellent properties as ORR catalyst support:

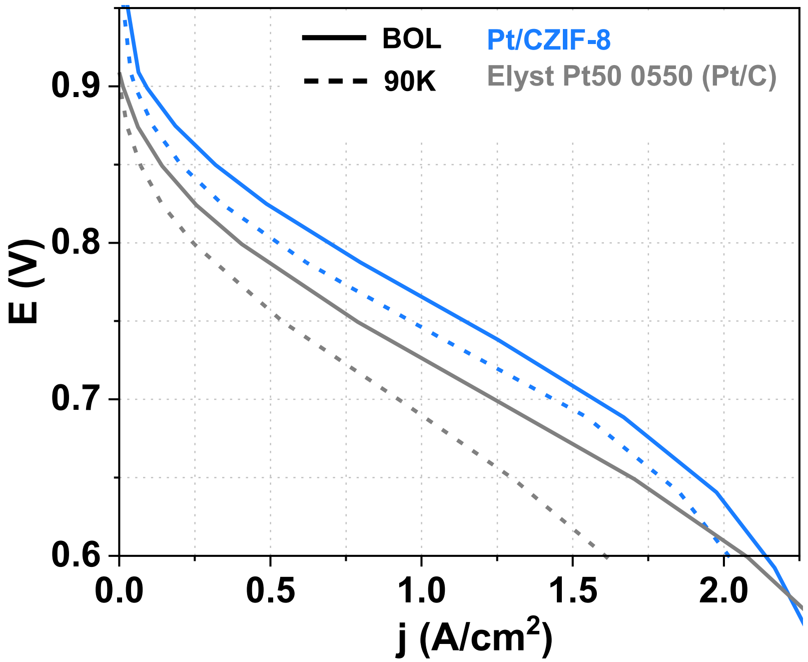
- Tunable balance of micropores and mesopores
- Tunable particle size with narrow distribution
- Abundant N doping for enhanced activity and durability

Pt/CZIF8





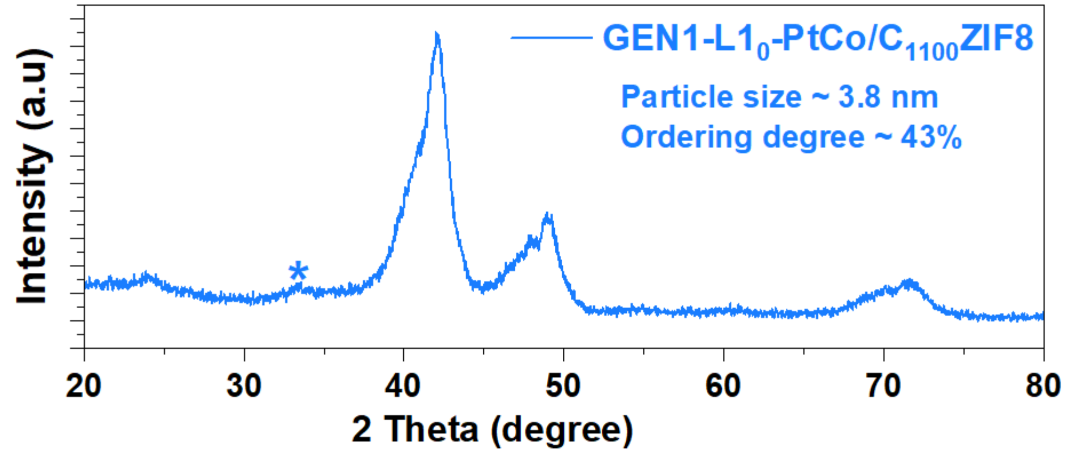


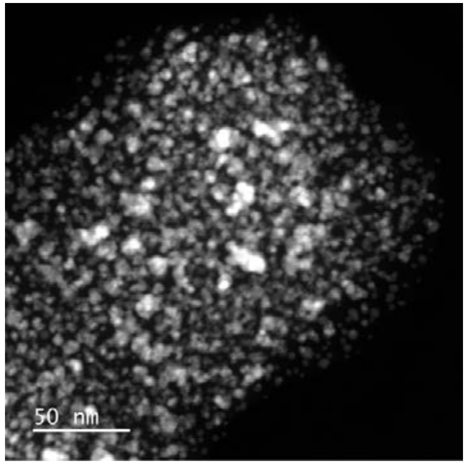


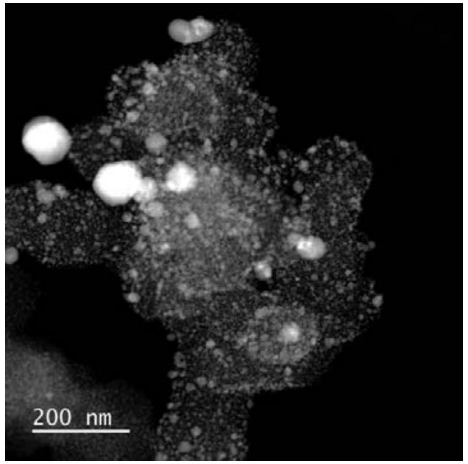
- Pt/CZIF8 catalyst provides 3.4 kW/gPGM (1.44 A/cm^2) @0.7 V after 90K catalyst AST cycles
- 90K performance @0.8 V of Pt/CZIF8 catalyst is more than 2X higher than M2FCT baseline

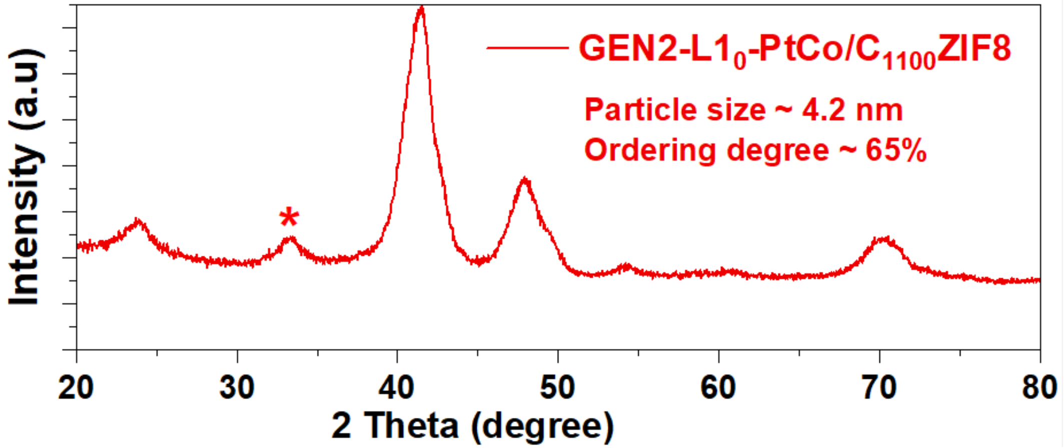
M2FCT conditions (250 kPa, 85% RH, 90°C, H_2/15% O_2), 5 cm^2 differential cell, NC700, 0.05/0.25 mg_{PGM}/cm^2

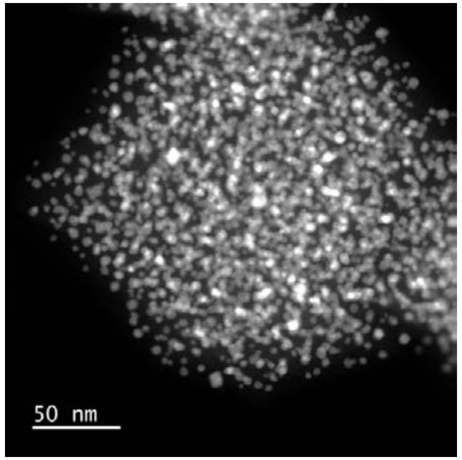
GEN2-L1_0-PtCo/CZIF8

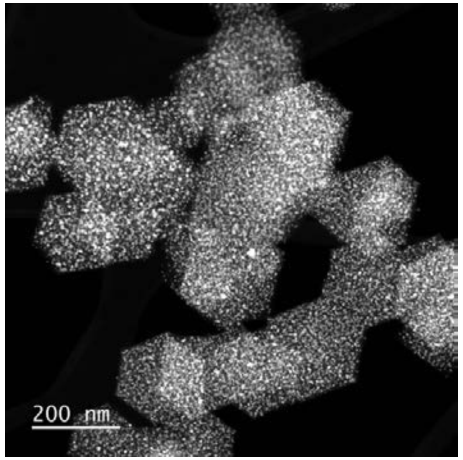






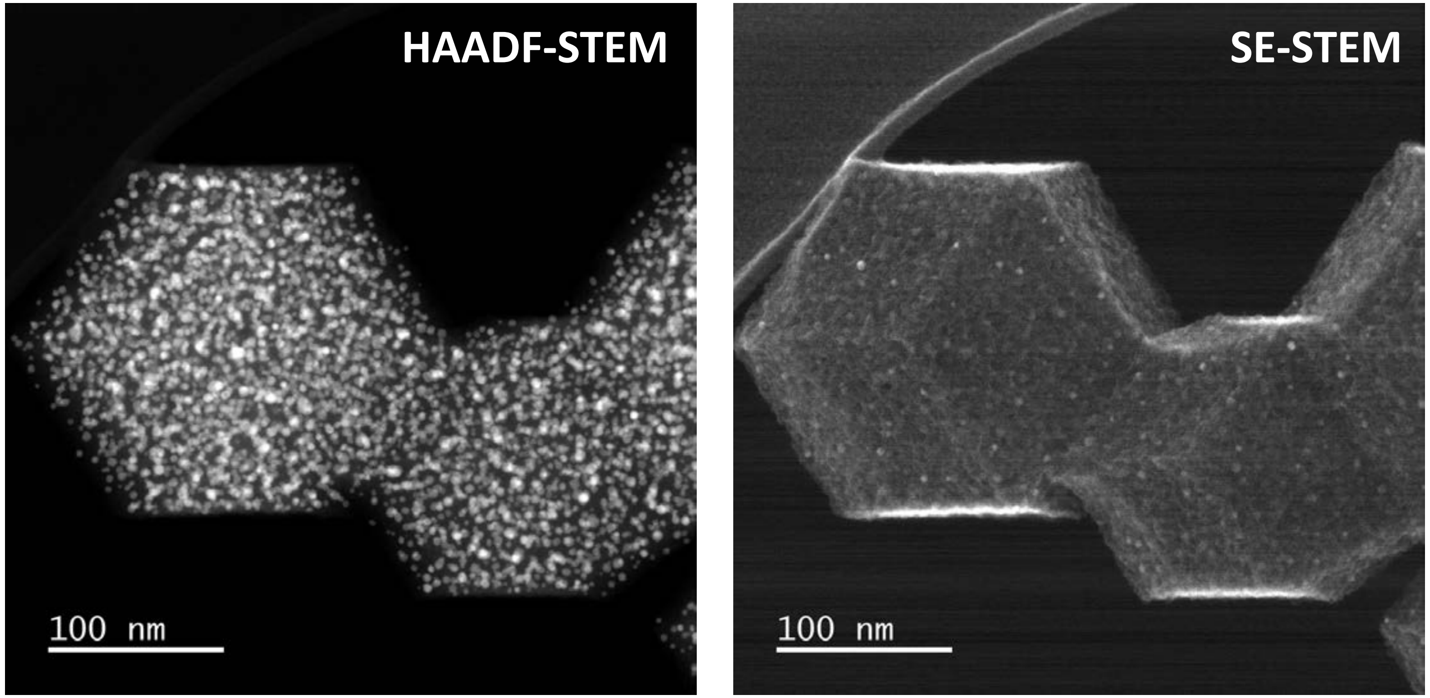


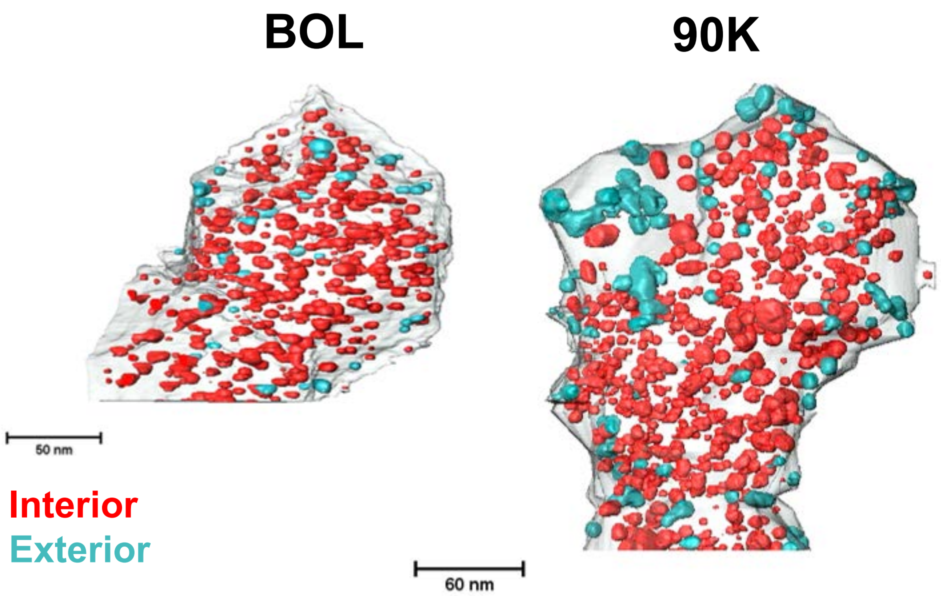


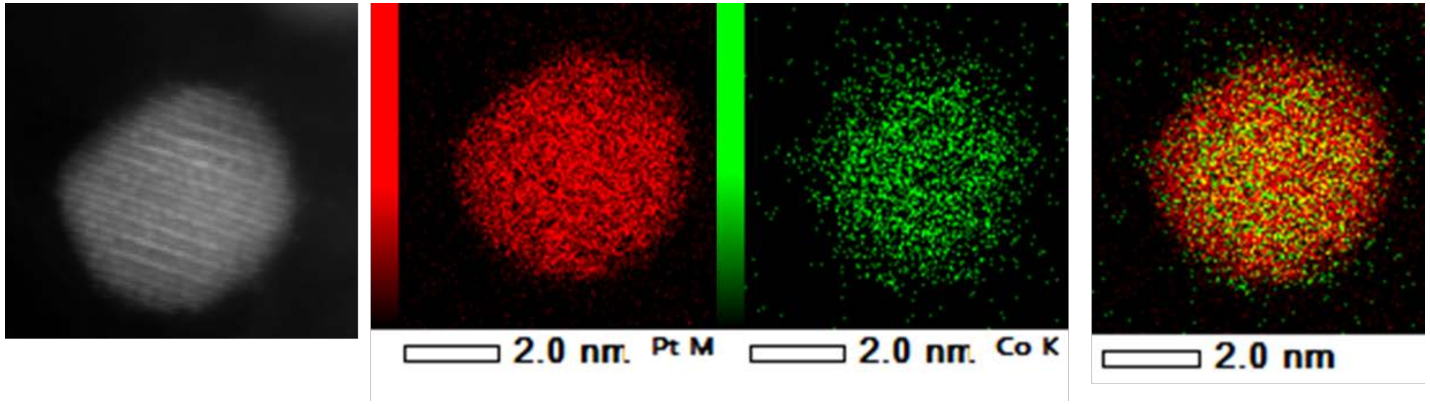


GEN2-L1_0-PtCo/CZIF8 has higher ordering and better particle dispersion

GEN2-$L1_0$-PtCo/CZIF8

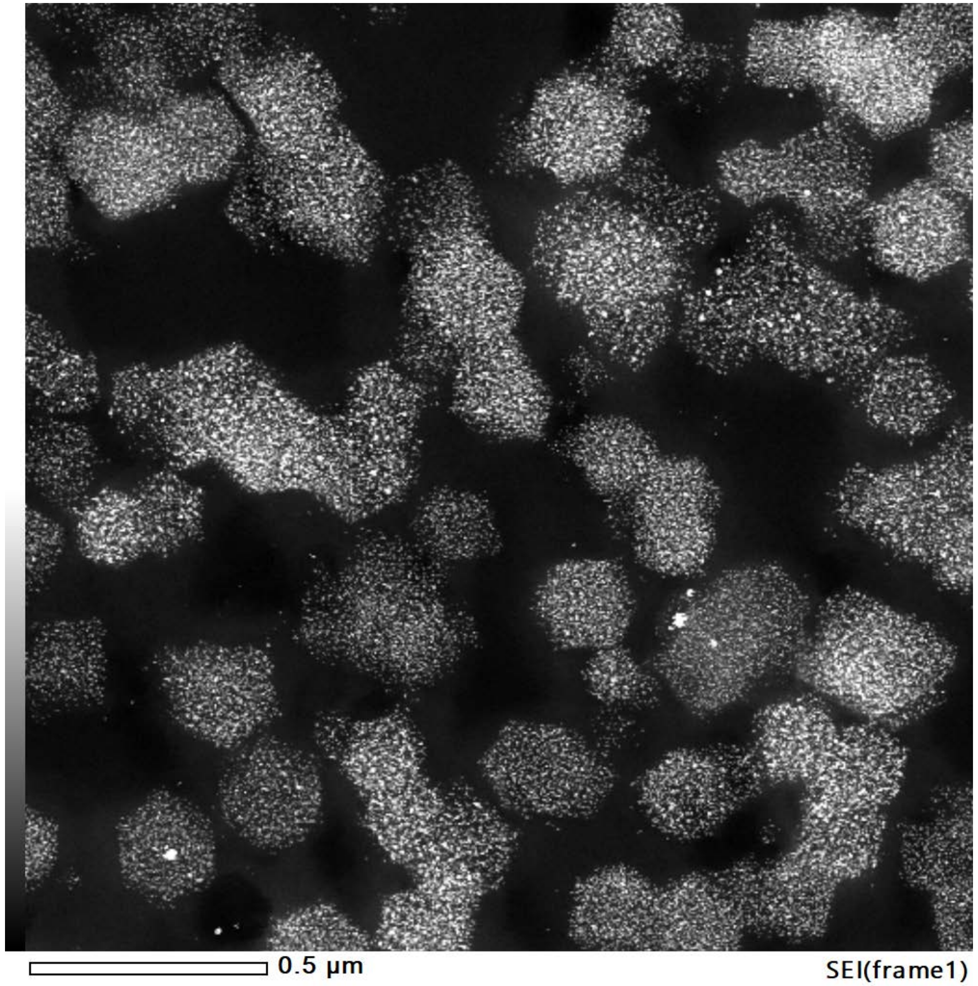


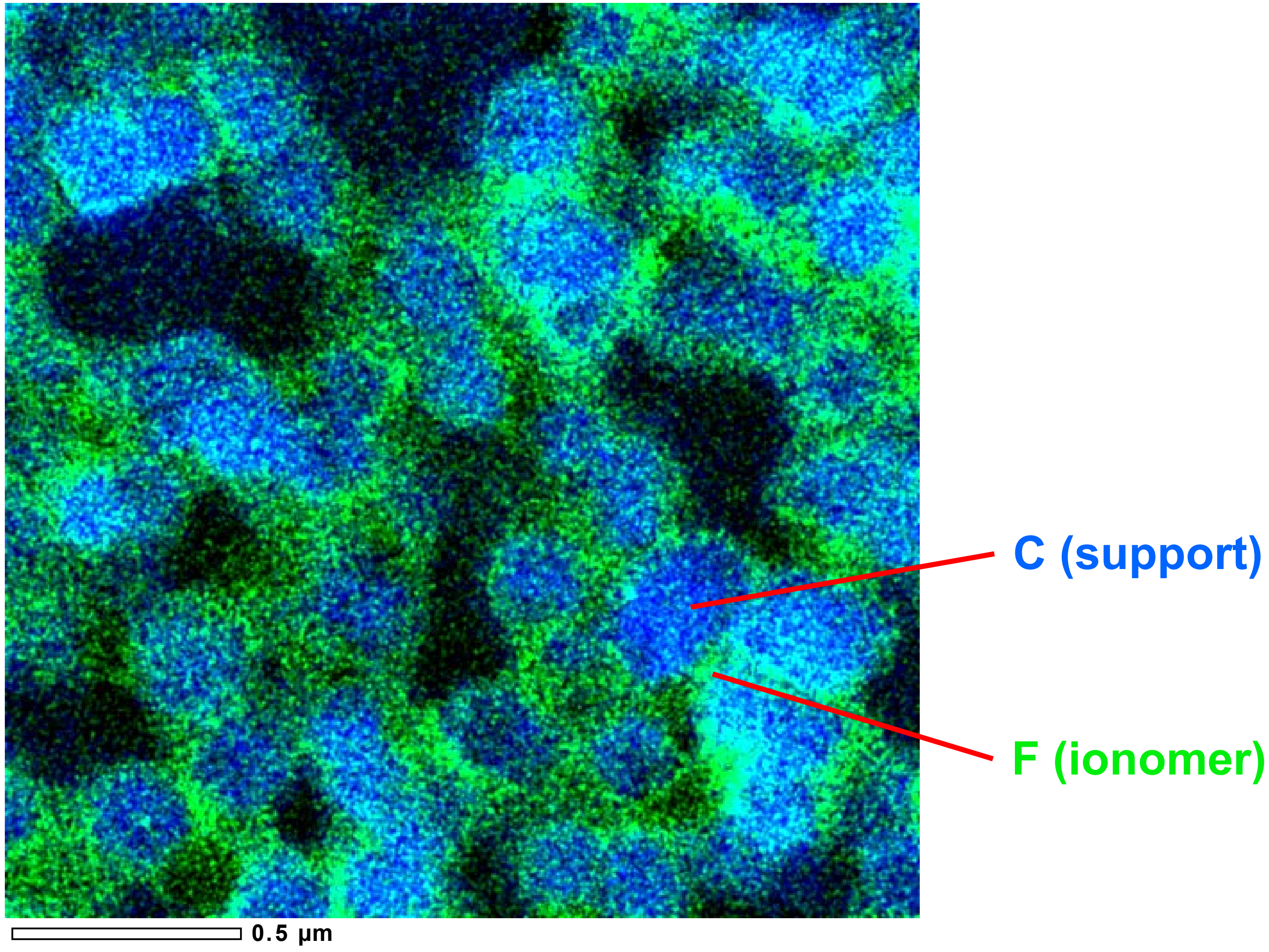




- >90% of PtCo particles located in CZIF8 interior – reduced degradation and reduced ionomer poisoning
- Uniform particle size distribution

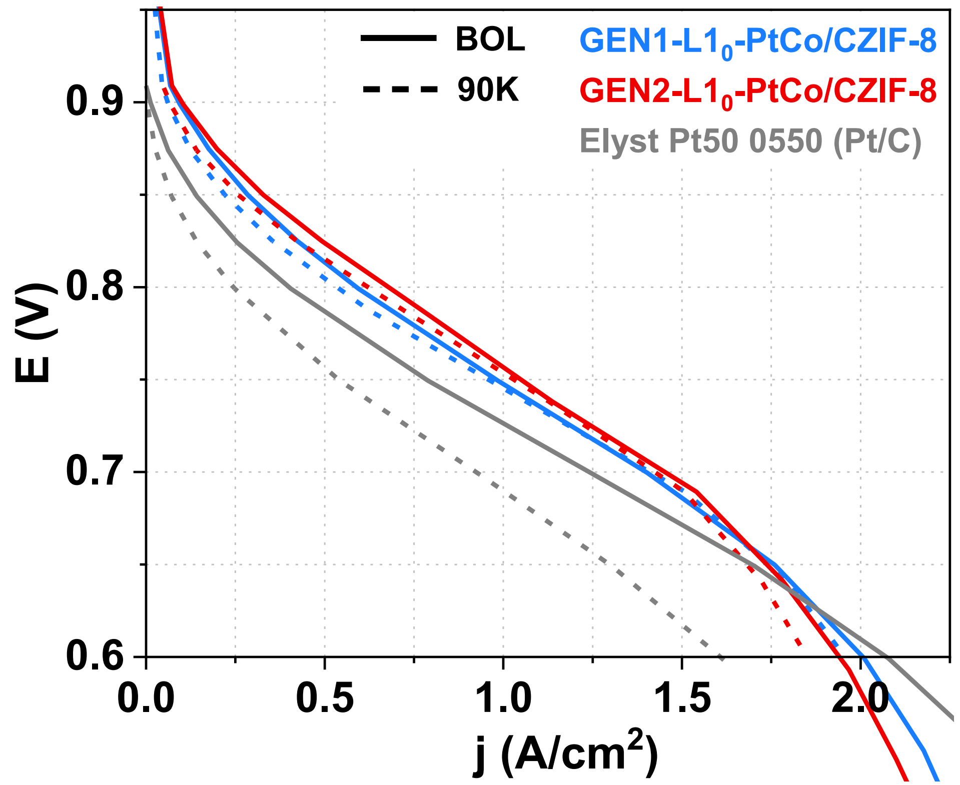
GEN2-L1_0-PtCo/CZIF8

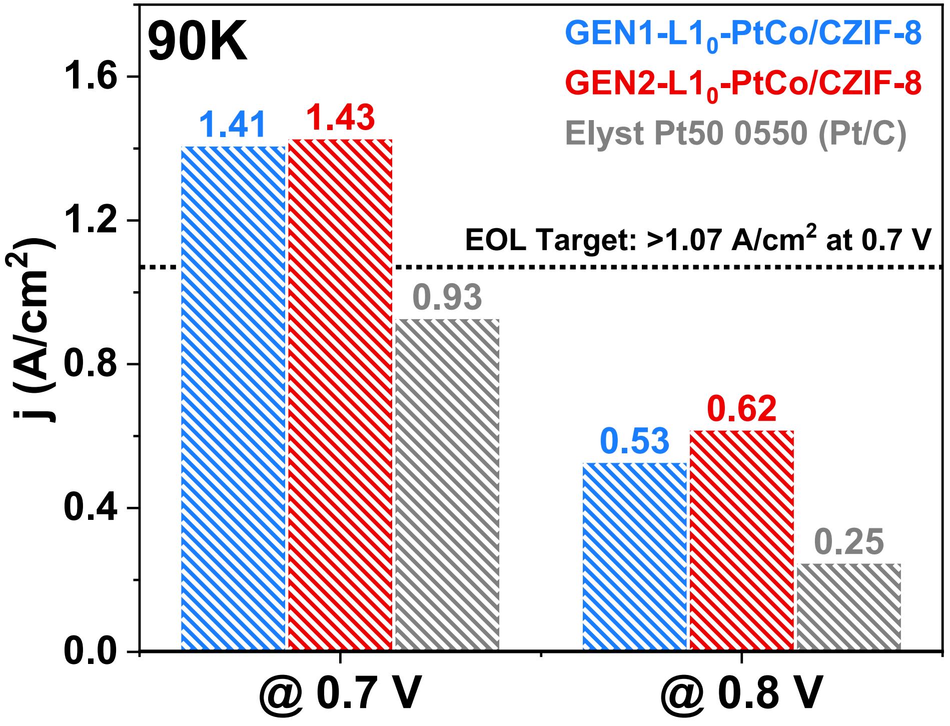




Electrodes show uniform ionomer distribution for H^+ transport, with abundant porosity for O_2 transport

GEN2-L1_0-PtCo/CZIF8





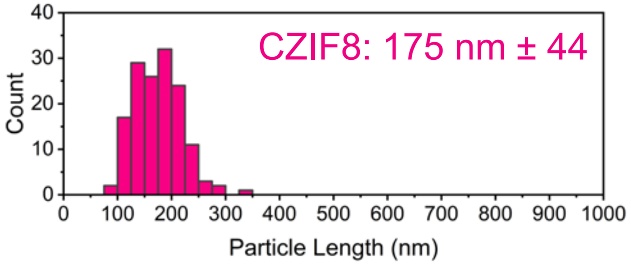
- **GEN2: 3.3 kW/g_{PGM} (1.43 A/cm^2) @0.7 V after 90K catalyst AST cycles**
- **90K performance @0.8 V of GEN2 catalyst is 17% higher than GEN1, 150% higher than M2FCT baseline**

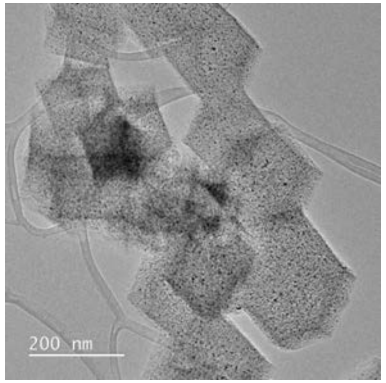
M2FCT conditions (250 kPa, 85% RH, 90°C, H_2/15% O_2), 5 cm^2 differential cell, NC700, 0.05/0.25 mg_{PGM}/cm^2

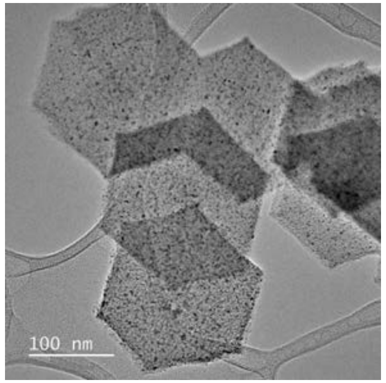
90K cycles from 0.6-0.95 V with 0.5 s ramp and 2.5 s soak

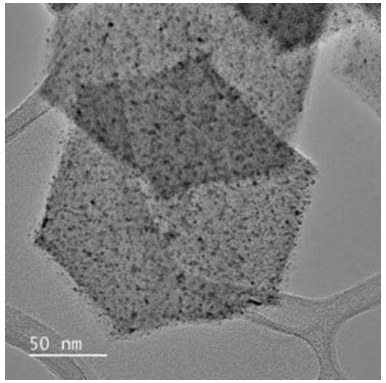
Scaleup: 10 g Batches

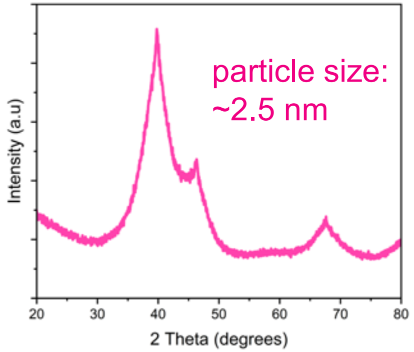
0.1 g batch



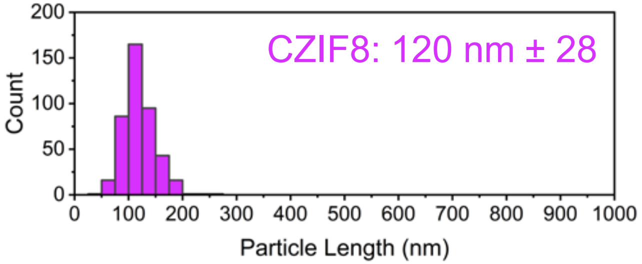


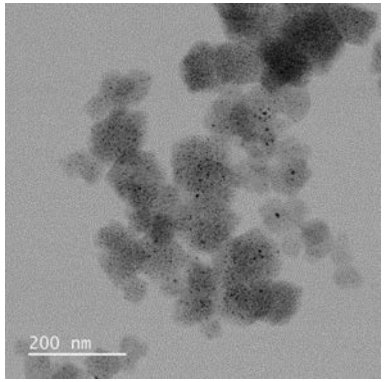


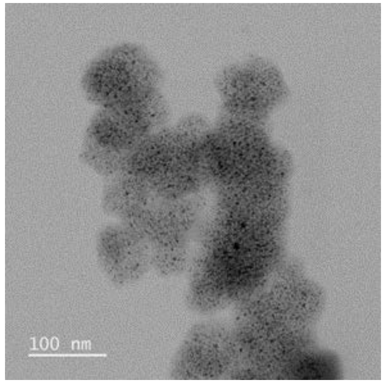


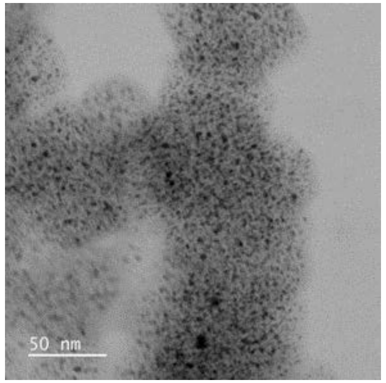


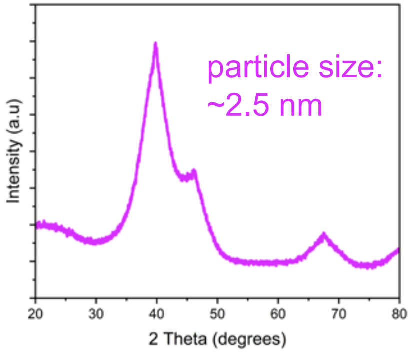
10 g batch





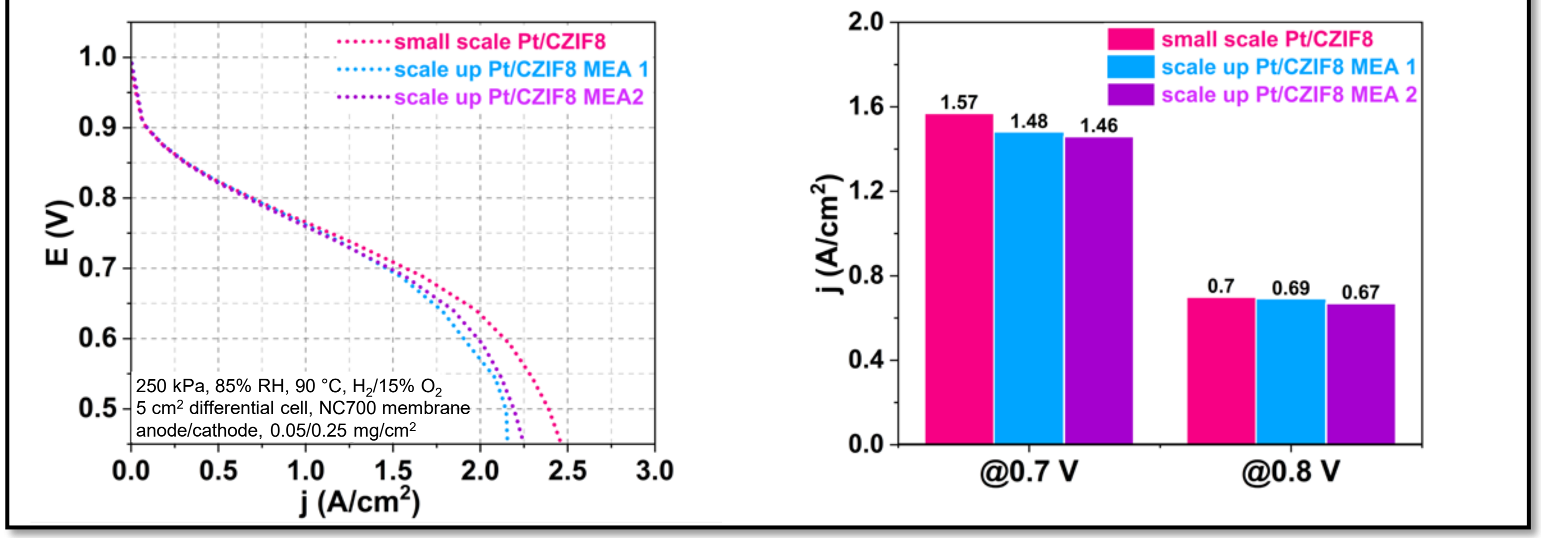




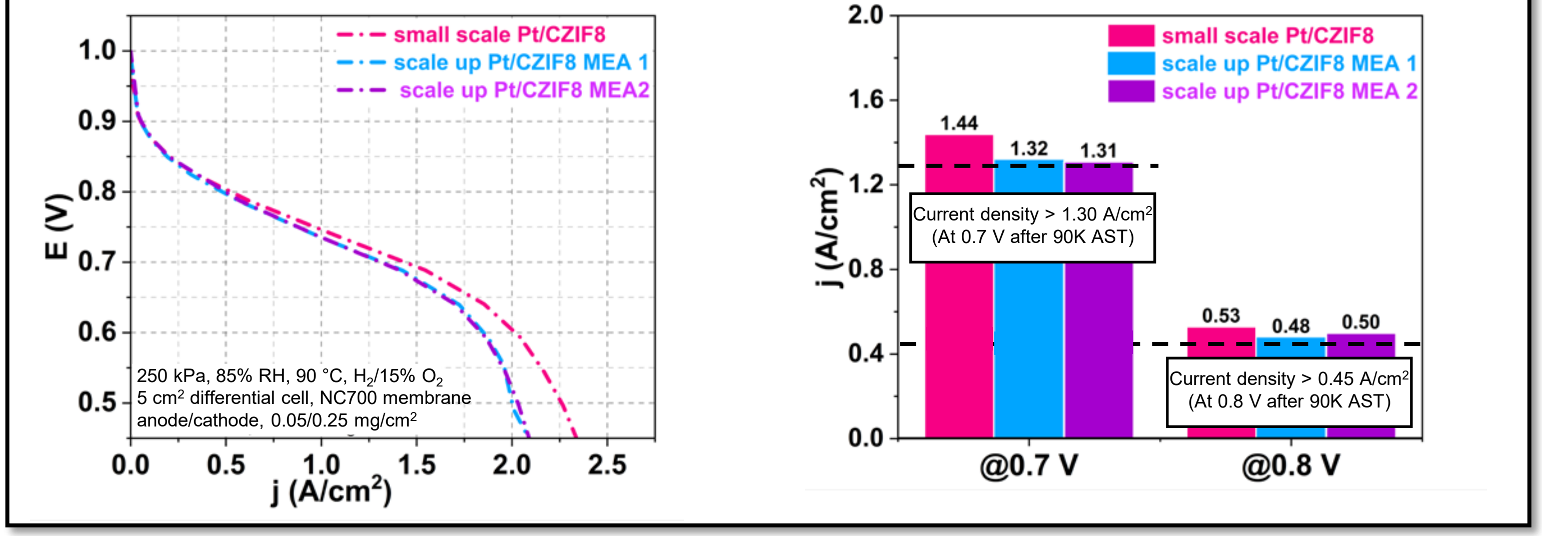


Scaleup: 10 g Batches

BOL

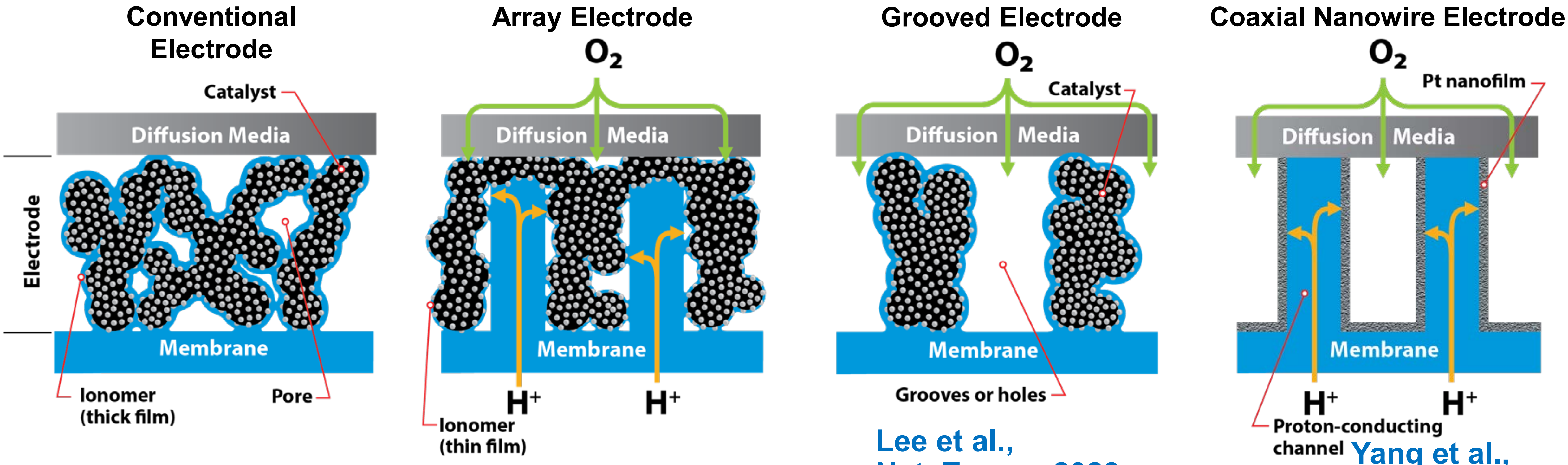


90K



Pt/CZIF8 successfully scaled up to 10 g batch with minimal loss in performance/durability

Structured Electrode Designs



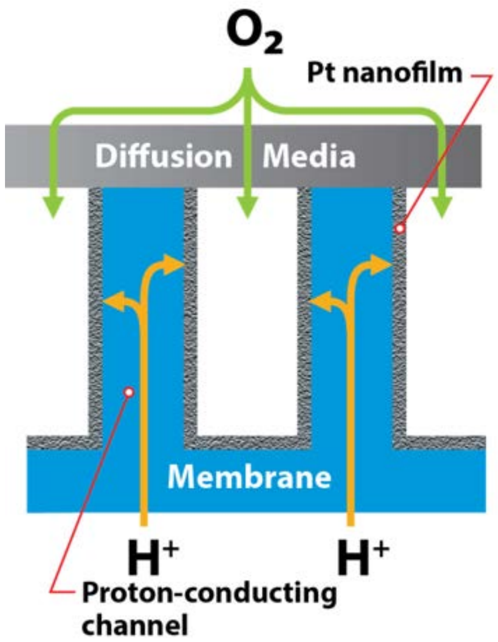
Lee et al., Nat. Energy 2023

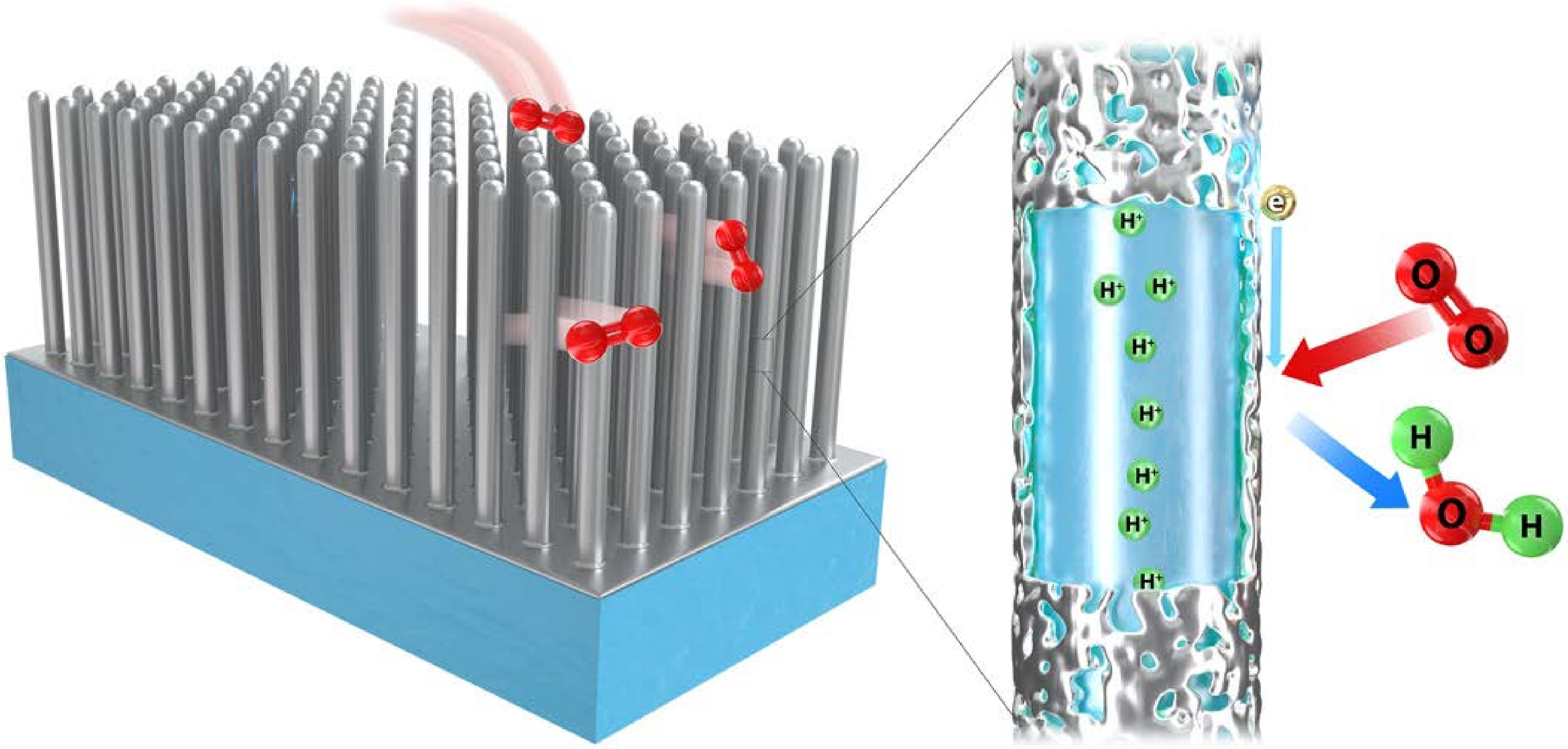
Yang et al., Adv. Mat. 2023

Structured electrodes have three key attributes:

1. **Differentiated.** Different electrode functions are separated into different segments, enabling each segment to be optimized for its specific function
2. **Ordered.** Ordered arrays of straight-through transport channels reduce tortuosity and non-percolation
3. **Hierarchical.** Control of structural features on multiple length scales is used to maximize transport rates and interfacial area

Co-axial Nanowire Electrode (CANE)





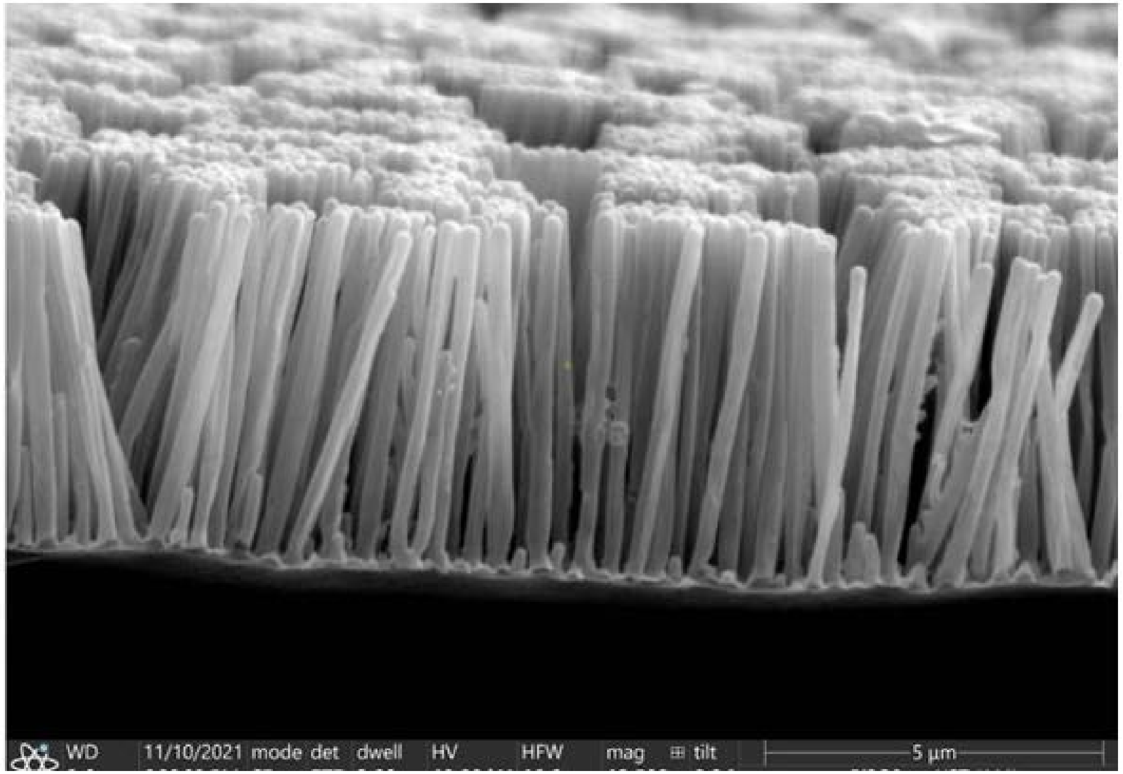
CANE reimagines how an electrode should look:

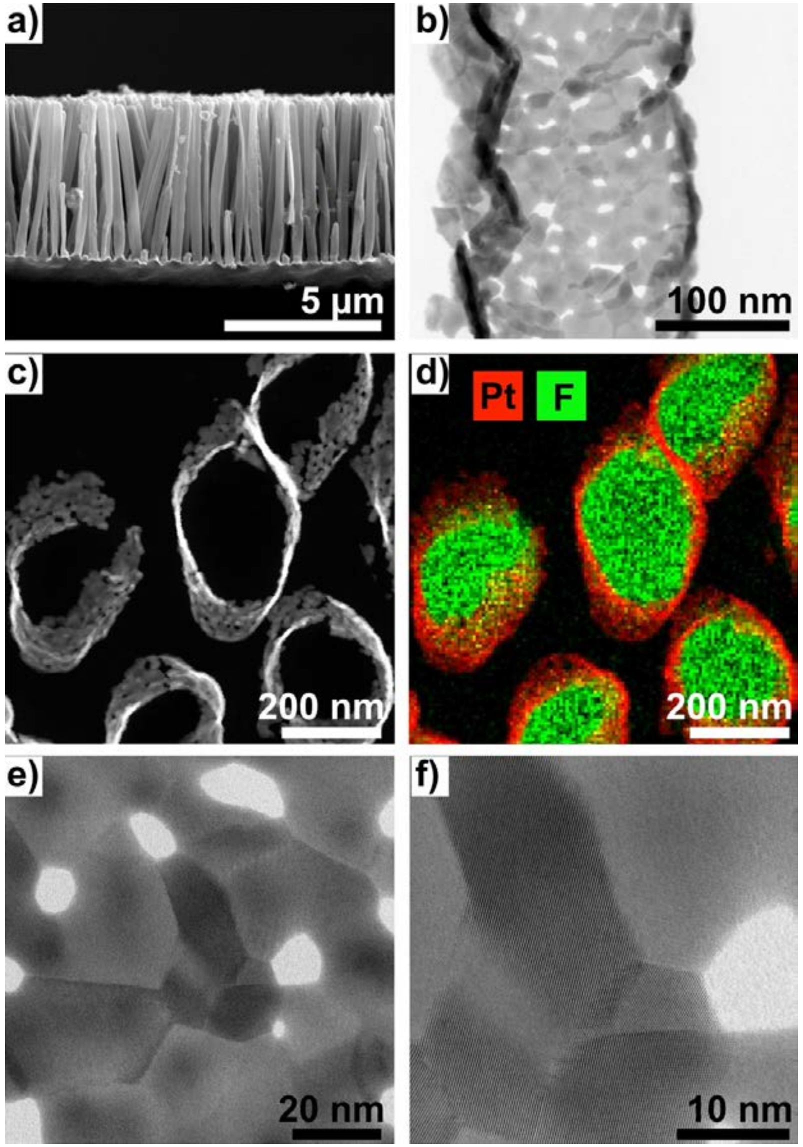
- Replaces unstable Pt/C with durable Pt nanofilms
- Replaces random and tortuous structure with an ordered array of non-tortuous transport channels

Yang et al., Adv. Mat. (2023) 2301264

Co-axial Nanowire Electrode (CANE)

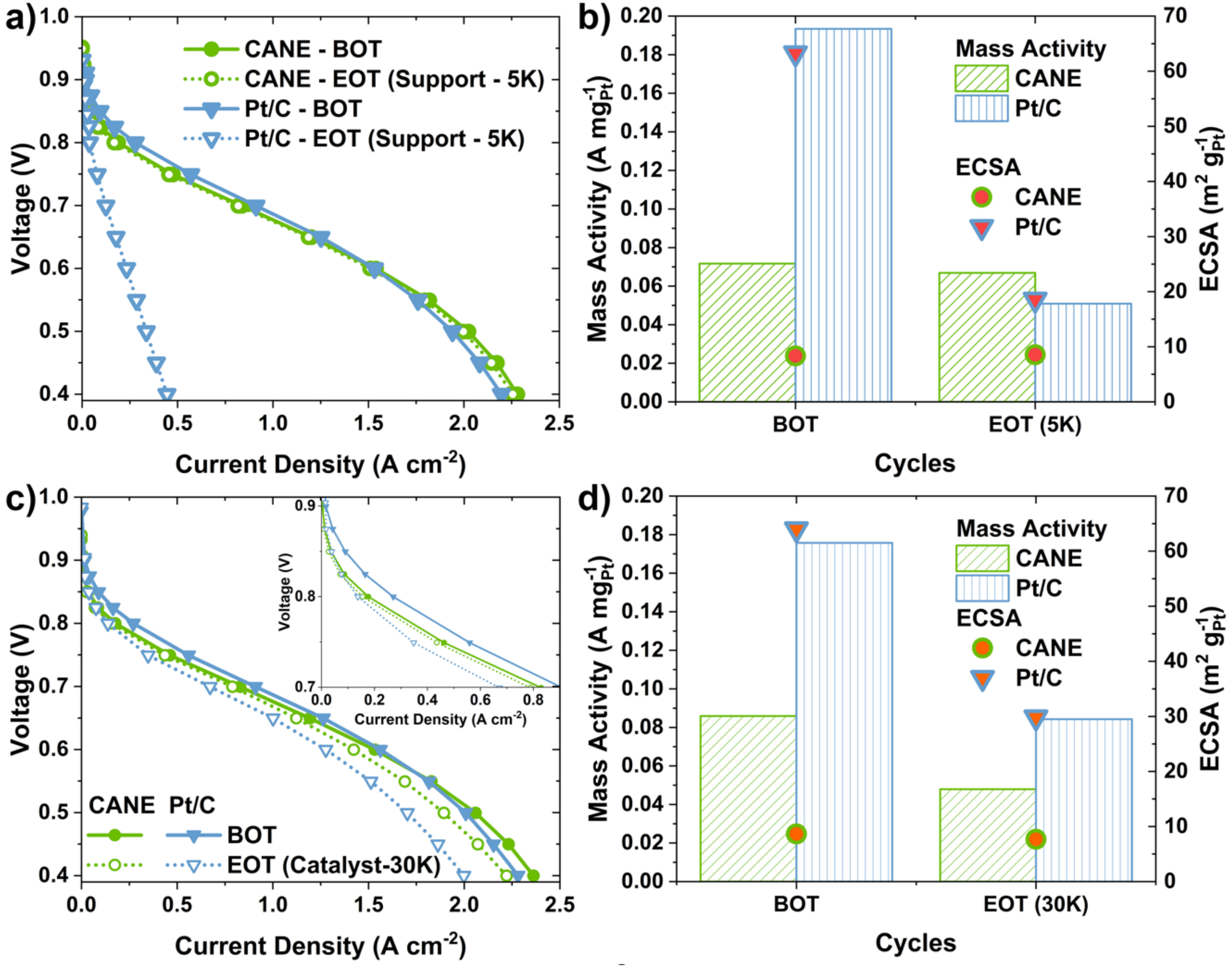
- CANE has ionomer-free Pt surfaces - can reduce catalyst poisoning and O_2 transport resistance
- Nanowire ionomer channels provide H^+ transport and mechanical support





Yang et al., Adv. Mat. (2023) 2301264

Co-axial Nanowire Electrode Performance

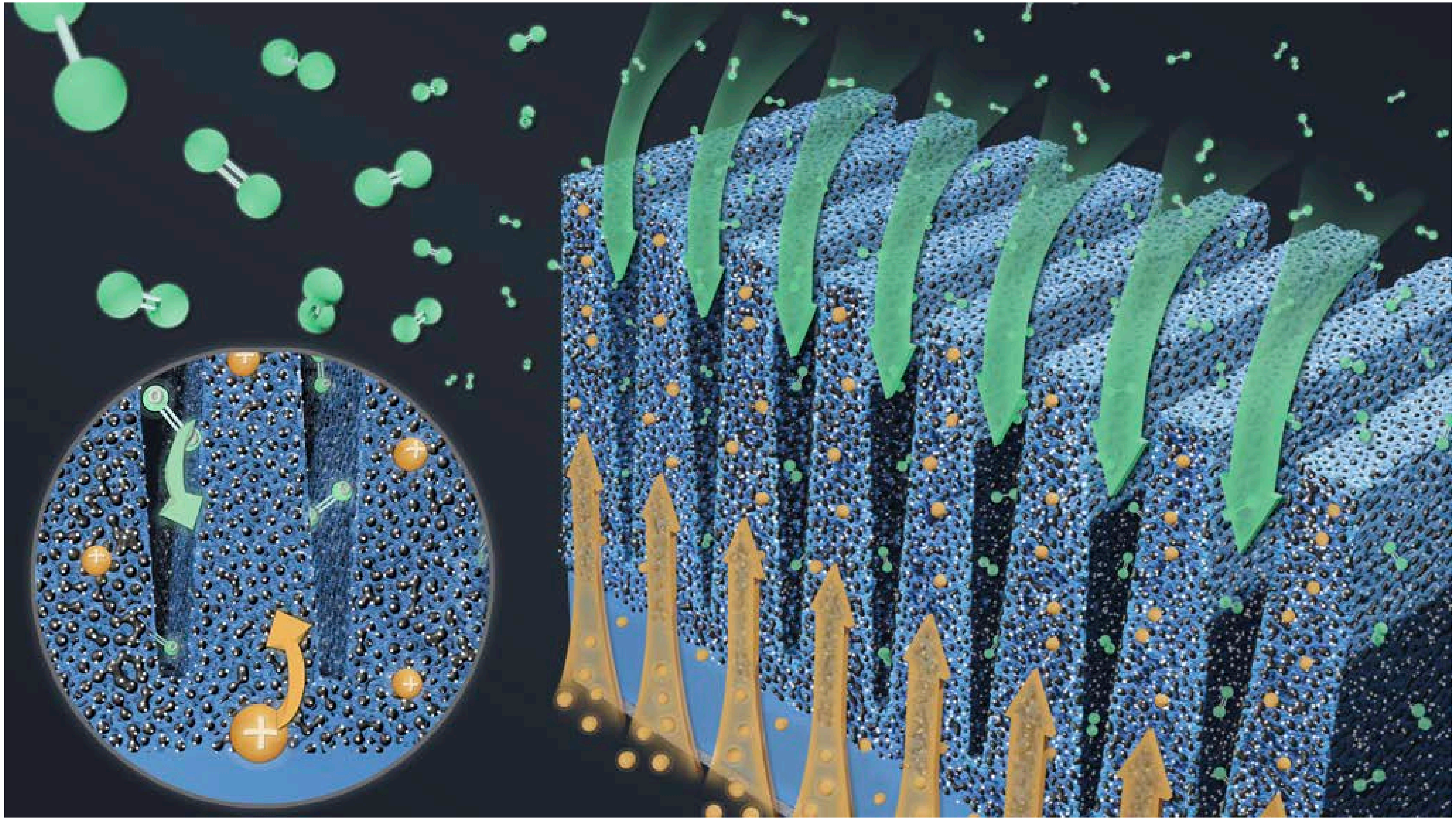


CANE provides extreme resistance to catalyst and electrode degradation

Performance loss at 0.7 V

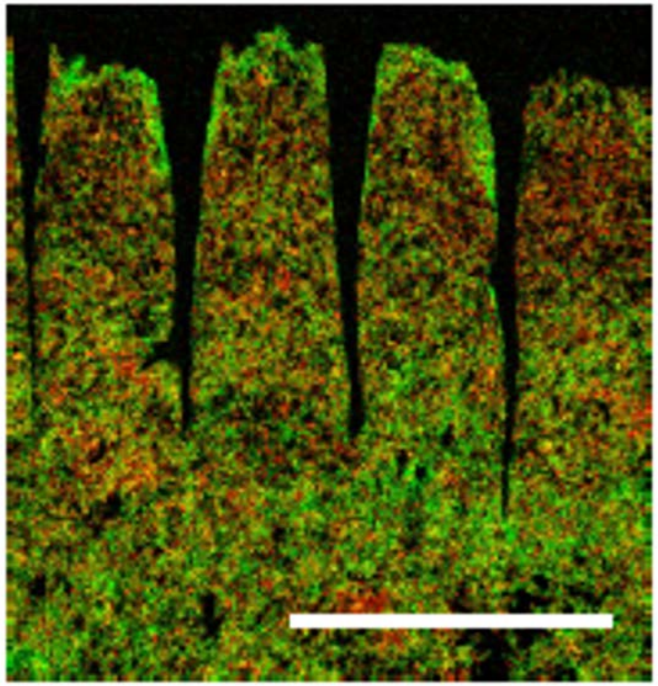
	CANE	20% Pt/Vu
Catalyst AST	5%	27%
Support AST	2%	87%

Grooved Electrodes



Two main features:

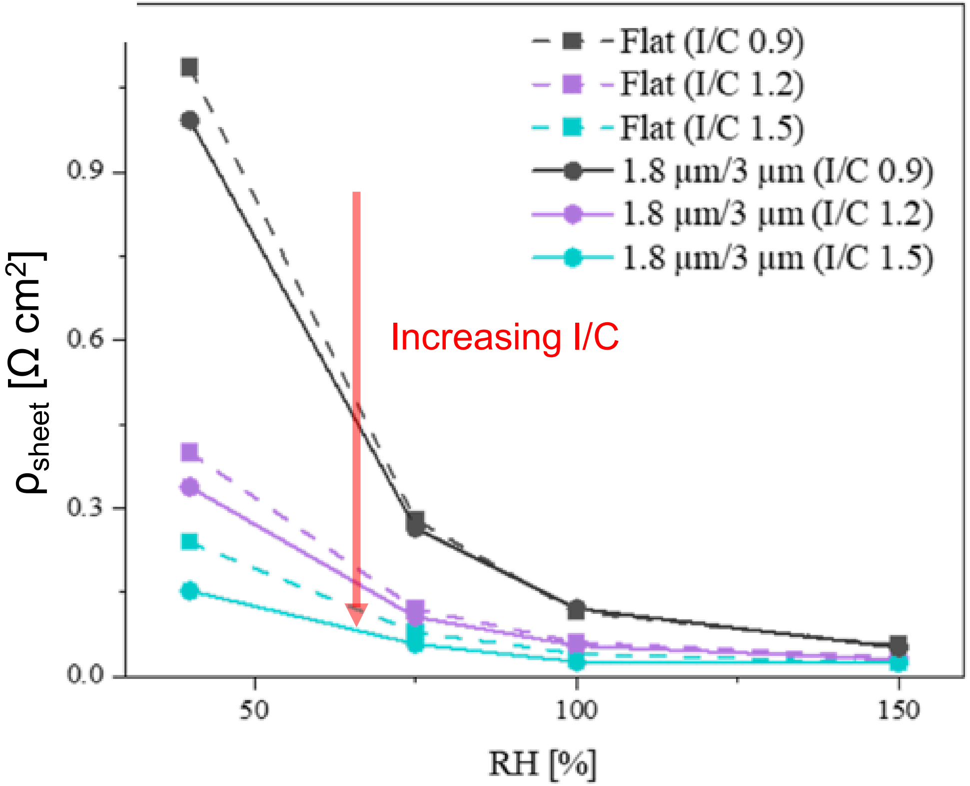
1. High I/C ratio electrode ridges: **H^+ transport**
2. Grooves: **O_2 transport**



Lee et al., Nature Energy 8 (2023) 685–694

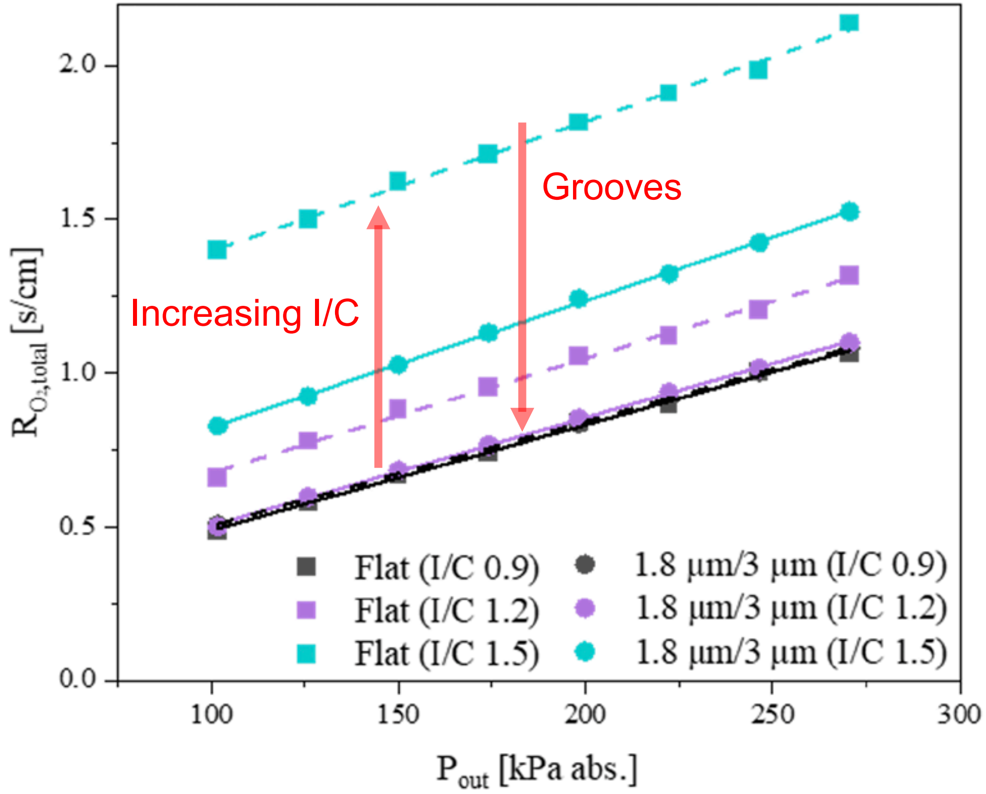
H^+/O_2 Transport Resistance

H^+ Transport Resistance



- Increase in I/C reduces H^+ resistance
- 60% decrease (groovy I/C 1.2 vs. flat I/C 0.9) at 100% RH

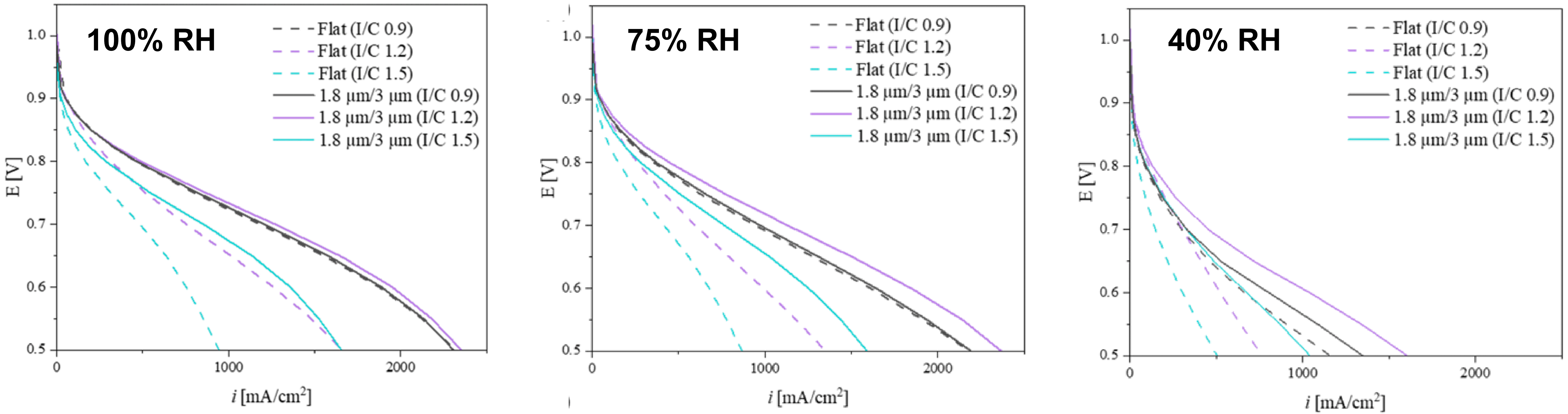
O_2 Transport Resistance



- Higher RO_2 at higher I/C
- R_{O2} of groovy (I/C 1.2) ≈ flat (I/C 0.9)

Grooves enable use of higher I/C, improving H^+ transport, without hurting O_2 transport

Enhanced Performance with Grooved Electrodes

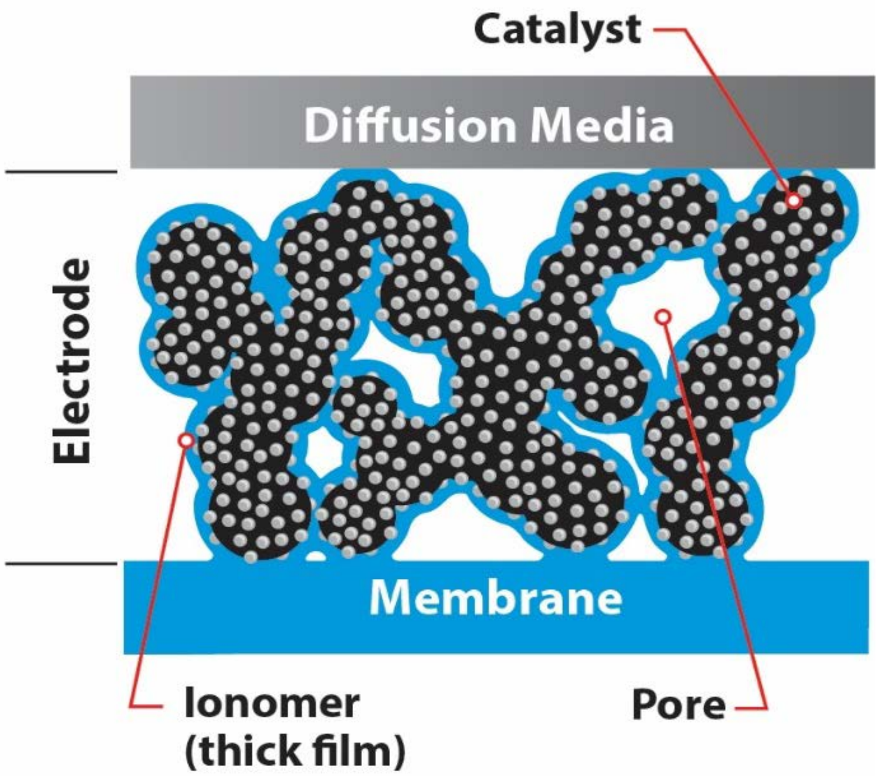


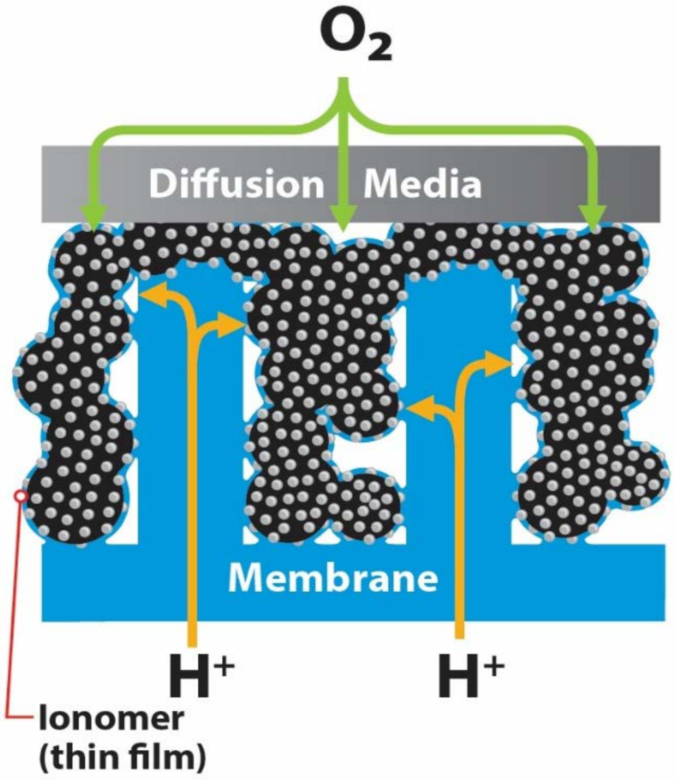
Cell: 0.3 mg_{Pt}/cm^2, TEC10E40E, N211, SGL 22BB
Testing: 5 cm^2 differential, 1000/3000 sccm H_2/Air, 150 kPa, 80°C

- Grooves had negligible effect at I/C 0.9
- Grooves improved performance at I/C 1.2 and 1.5
  - 1.8 µm/3 µm (I/C 1.2) outperformed the baseline electrode (I/C 0.9) under all conditions
  - Performance was particularly enhanced under drier conditions

Lee et al., Nature Energy 8 (2023) 685–694

Array Electrodes





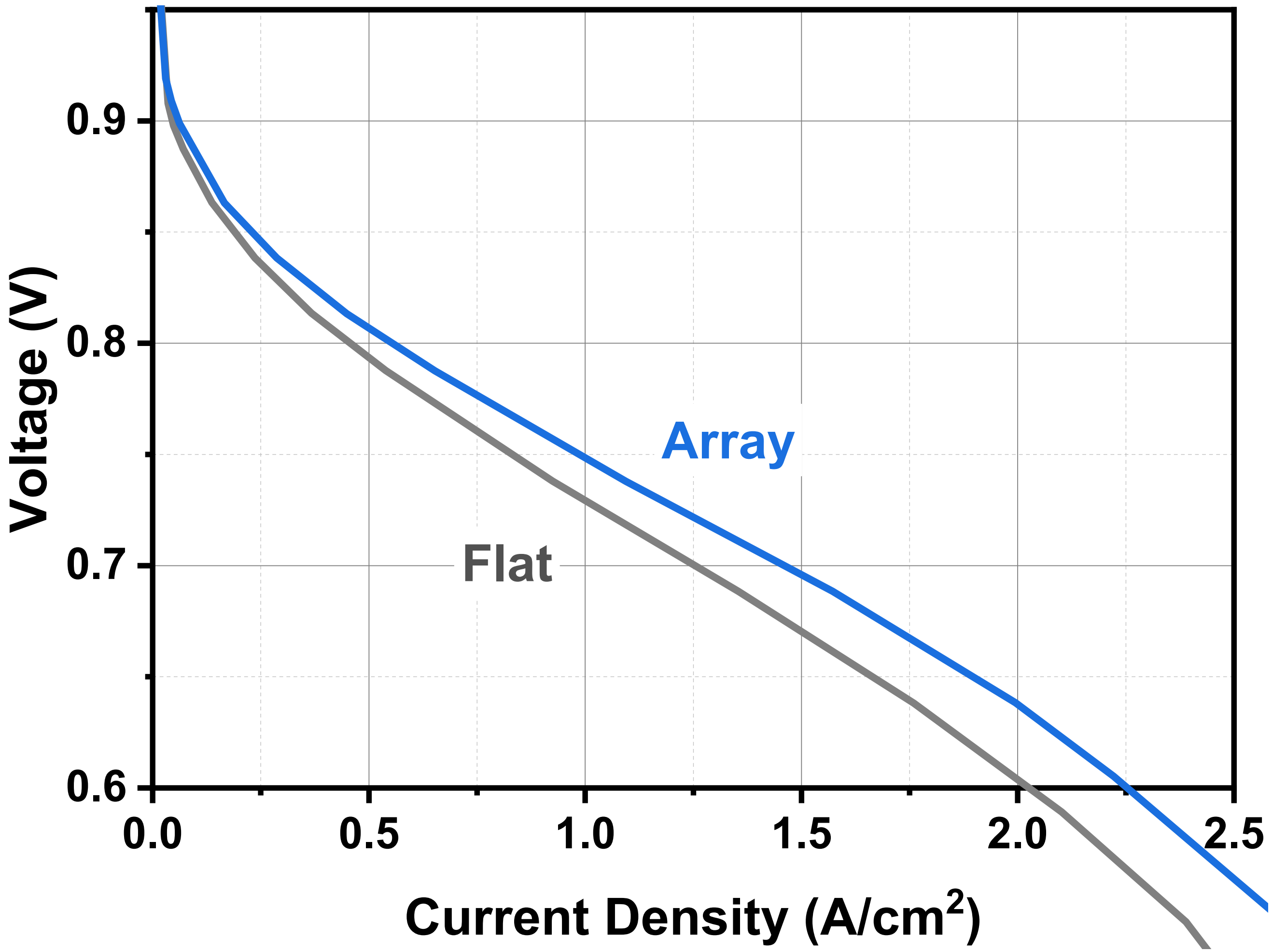
Conventional Electrode Properties:

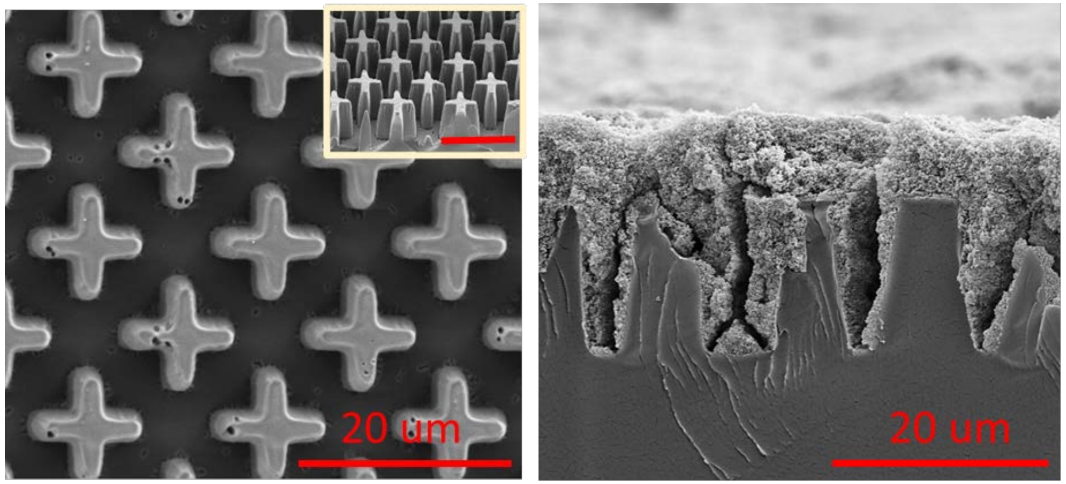
- Randomly oriented ionomer leads to tortuous proton pathways
- High ionomer content causes significant O_2 diffusion resistance

Array Electrode Properties:

- Vertically-aligned ionomer channels for improved proton transport
- Reduced ionomer content in catalyst layer improves O_2 diffusion and reduces poisoning

Array Electrodes





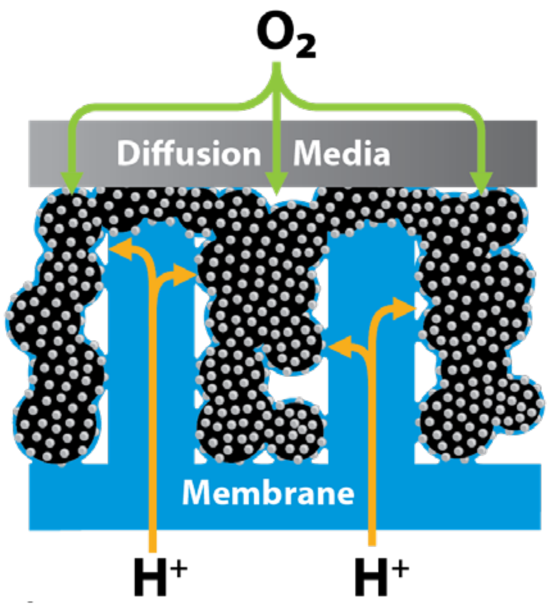
Performance enhancement:

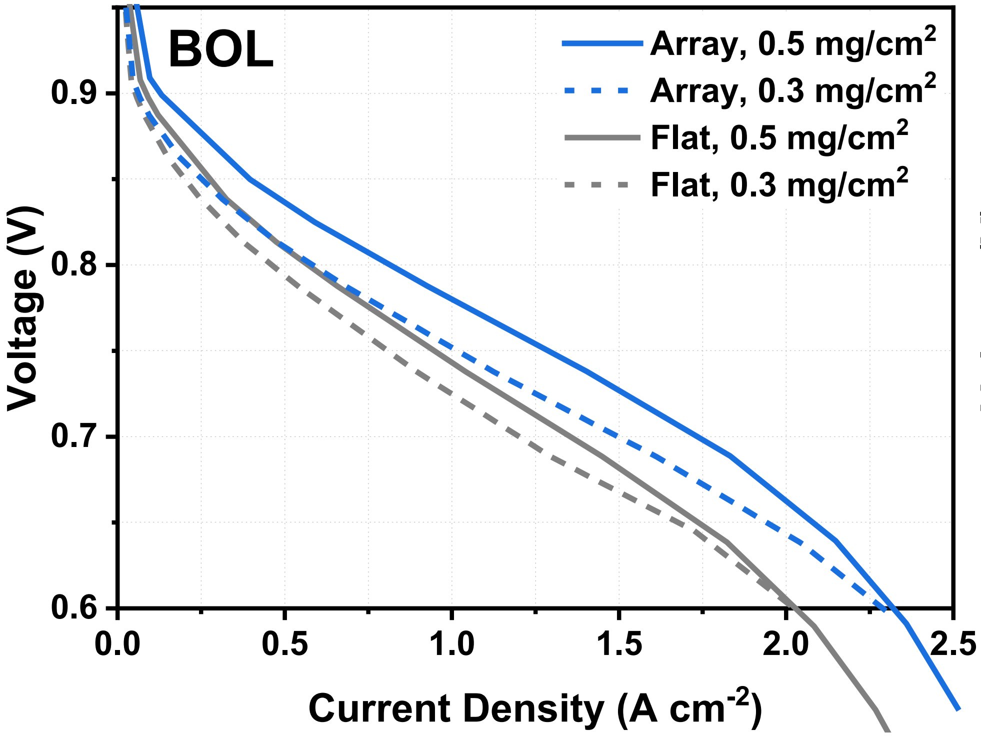
- 1.46 A/cm^2 @0.7 V, 16% higher
- 0.55 A/cm^2 @0.8 V, 20% higher

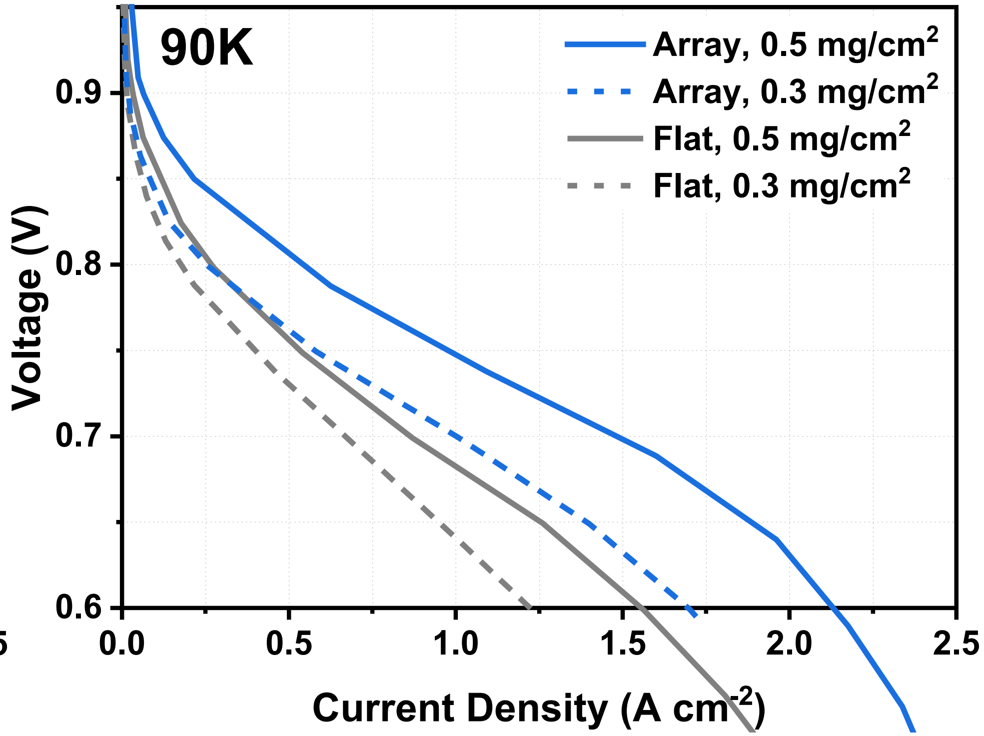
Array electrodes enhance H^+ and O_2 transport

150 kPa, 100% RH, 80°C, H_2/Air; 0.3 mg_{Pt}/cm^2 cathode and 0.1 mg_{Pt}/cm^2 anode loading; 5 cm^2 differential cell, NR-211

Array Electrodes to Enable Higher Loading





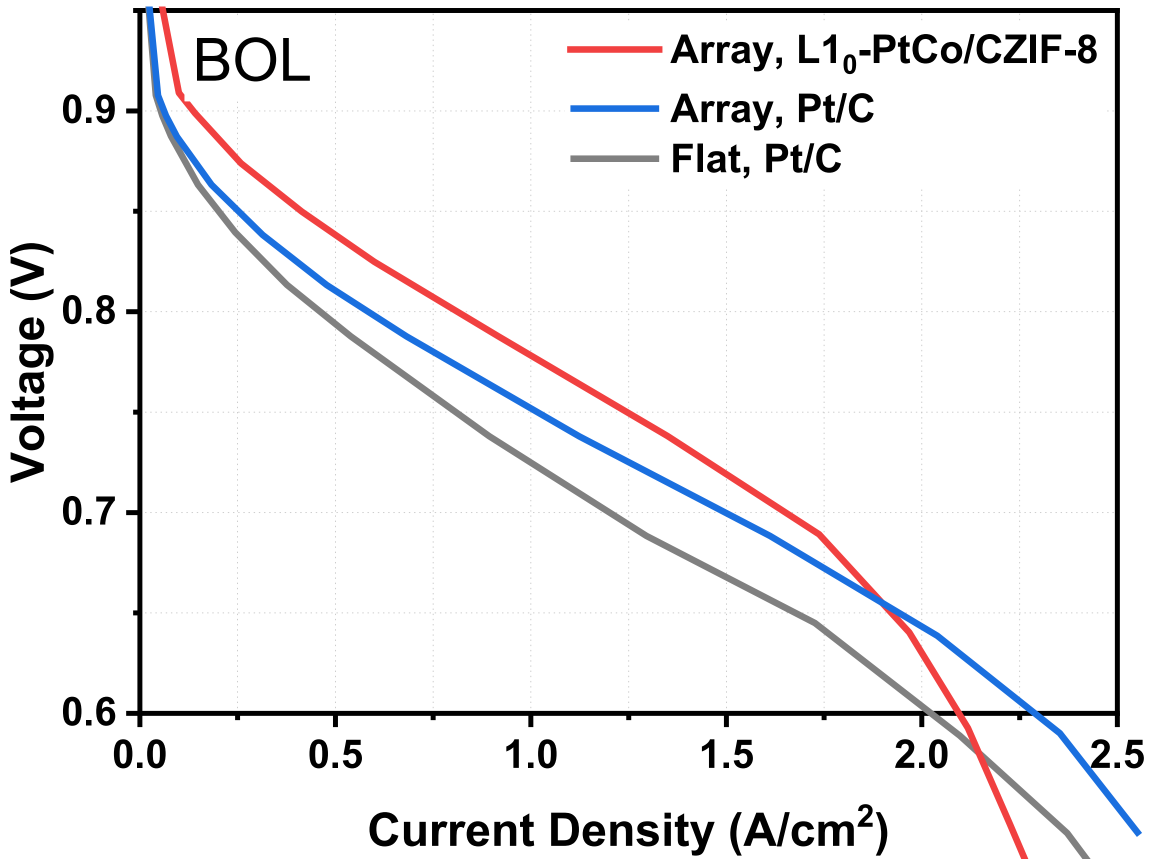


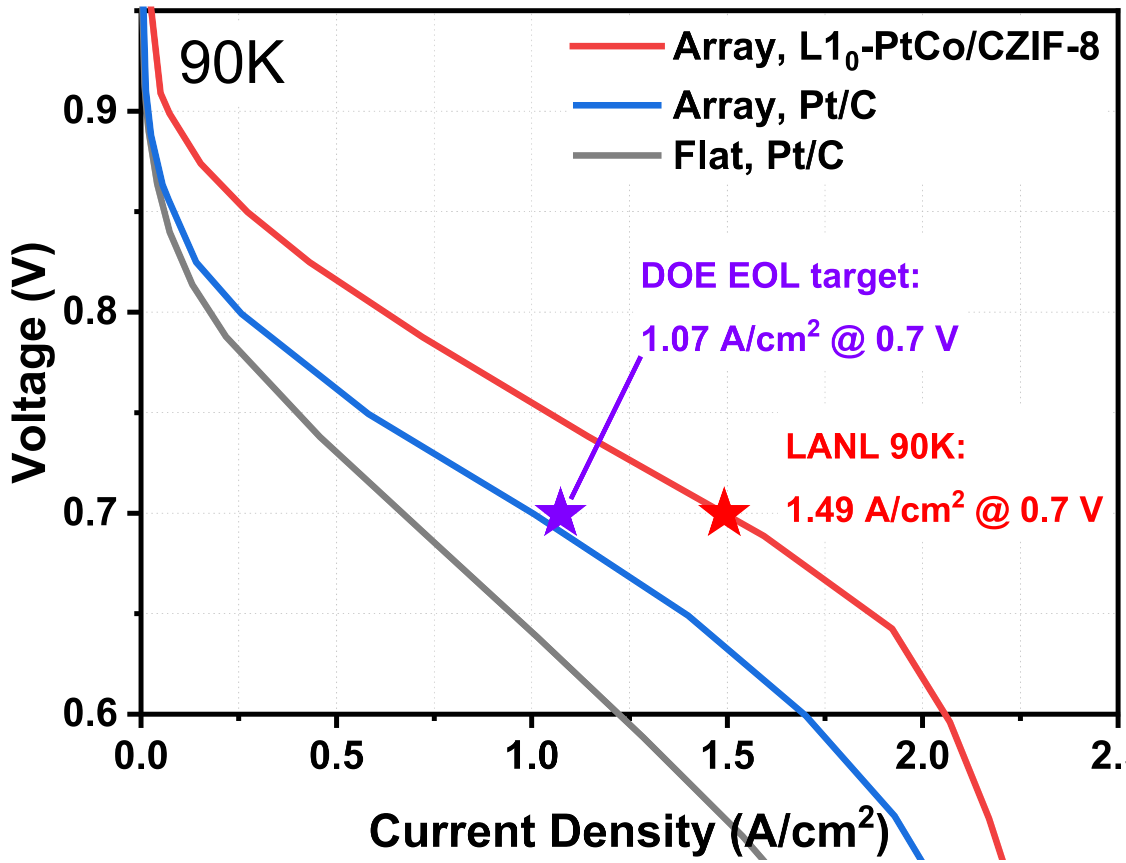
- Performance enhancement at 0.8 V:
  - 26% at 0.3 mg/cm^2
  - 44% at 0.5 mg/cm^2
- Performance loss after AST:
  - 15% for Array
  - 36% for Flat

Array electrodes provide fast transport even in thick HDV electrodes, enabling higher performance and durability

M2FCT conditions (250 kPa, 85% RH, 90°C, H_2/15% O_2), 5 cm^2 differential cell, NR-211, 0.1 mg$_{Pt}$/cm^2 anode loading; Cathode catalyst is TEC10E40E;

Advanced Catalysts in Advanced Electrodes





Advanced catalyst + array electrode provides ultrahigh performance and durability

M2FCT conditions (250 kPa, 85% RH, 90°C, H_2/15% O_2), 5 cm^2 differential cell, NR-211
Loadings: 0.05/0.25 mg$_{PGM}$/cm^2 (PtCo), 0.1/0.30 mg$_{PGM}$/cm^2 (Pt); Pt/C: TEC10E40E

Acknowledgements

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  - Greg Kleen, Dimitrios Papageorgopoulos
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- Center for Integrated Nanotechnologies (CINT)

L'Innovator 2.0 call posted at: https://www.lanl.gov/engage/collaboration/feynman-center/