Pure Hydrogen Production through Precious-Metal-Free Membrane Electrolysis of Dirty Water

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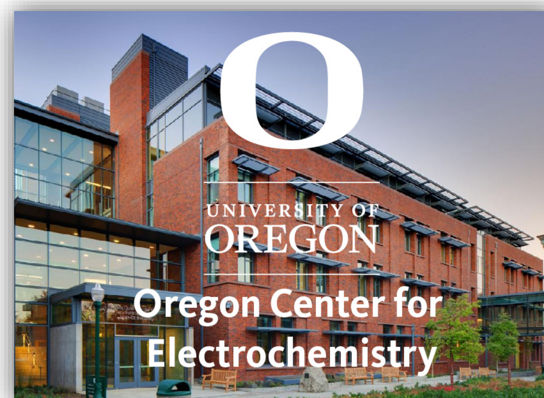


Project ID: P187

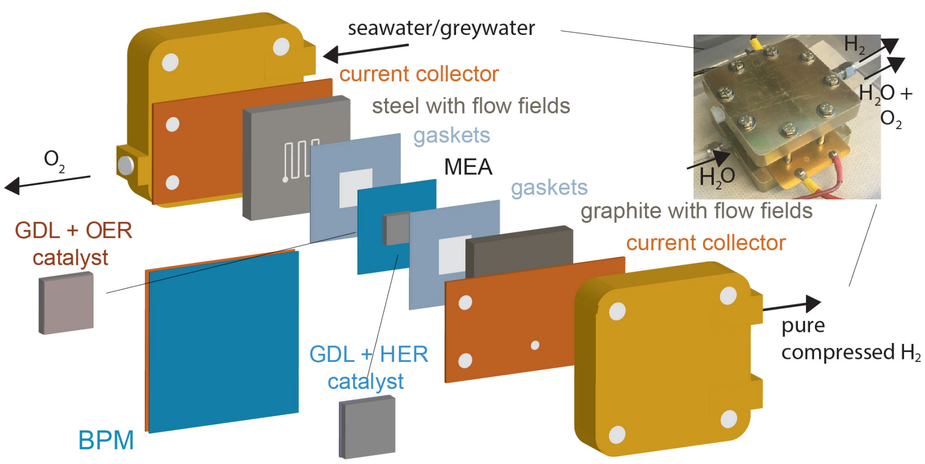
Project Overview

Project Partners

Shannon Boettcher, University of Oregon
HydroGEN nodes: Pivovar, Alia (NREL), Weber, Danilovic, Kusoglu (LBNL), Fujimoto (SNL)

Project Vision

Develop a technical understanding of performance degradation of alkaline and bipolar membrane electrolyzers in pure and dirty water and engineer impurity tolerant systems.



Award #	EE0008841
Start/End Date	4/1/20 – 3/31/23
Total Project Value* Cost Share %	$0.625 M (DOE+Cost Share) 20%

** this amount does not include cost share or support for HydroGEN resources leveraged by the project (which is provided separately by DOE)*
** We are still waiting for award setup so have not received any DOE funds to my knowledge to date*

Project Impact

Alkaline electrolysis systems enable PGM-free devices that may be more tolerant to impurities, if appropriately designed, which would increase system longevity, allow for less-stringent input water purity, and lower costs.

Relevance & Impact

- Program could lower costs and increase lifetime of electrolysis systems. ***Imagine* alkaline membrane electrolyzer with:**
  - performance equivalent to state of the art PEM
  - only earth abundant catalysts, and steel cell components
  - robust in operation in “dirty” water requiring less infrastructure and maintenance
- Project integrates broadly across HydroGEN consortium teams while leverage unique UO capabilities and experience.

Approach - Summary

Project Motivation

The need for ultra pure water in membrane electrolyzers increases system complexity, cost, maintenance, and failure points. We aim to design electrolyzers more intrinsically robust to 'dirty' water.

Key Impact

Metric	State of the Art	Expected Advance
BPM performance	*~ 1 V at 1 A cm^{-2}*	*< 100 mV at 1 A cm^{-2}*
Efficiency in 'dirty' water	N/A	< *2V at 2 A* cm^{-2}
Durability in 'dirty' water	N/A	< 4 mV / 100 h

Barriers

- Ion exchange in membrane(s)
  - Minimize by controlling ion flow direction
- Deposition of impurities
  - Use high loadings of low-cost catalyst, control location and morphology of deposits
- Cl^- oxidation
  - Maintain local basic anode

Partnerships

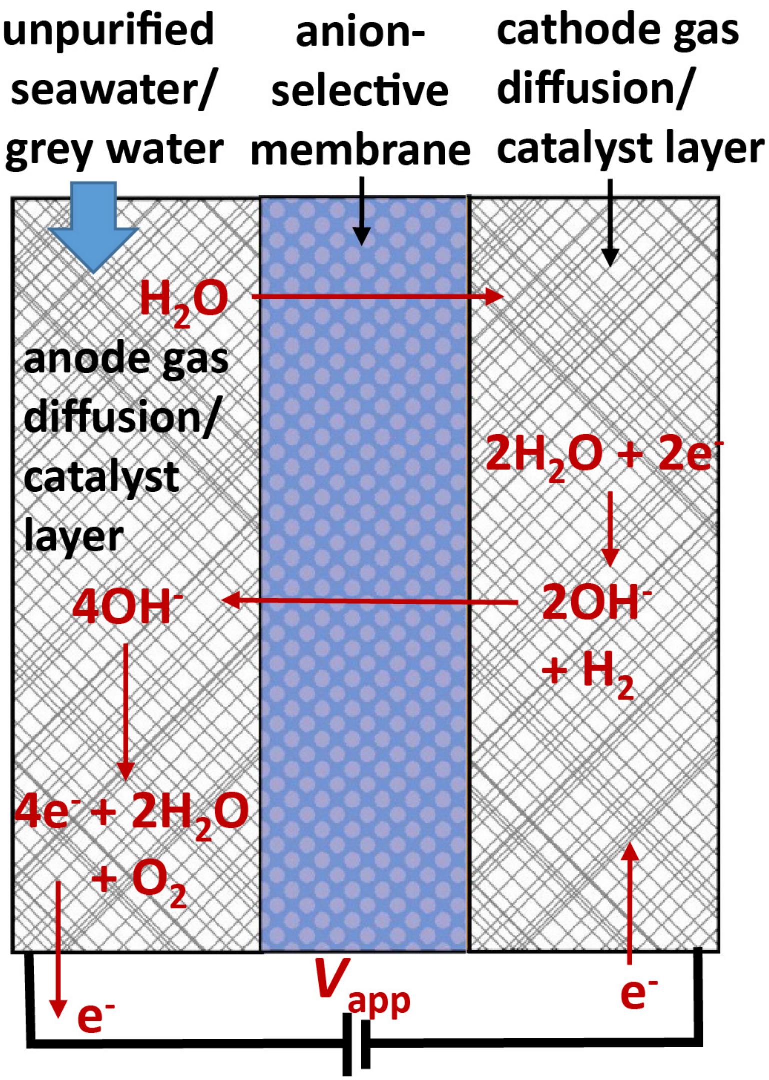
Key partners with HydroGEN network nodes, as described in following slides.

Approach - Innovation

- We will work to control ion flow in AEM and BPM electrolyzer architectures and understand degradation modes and strategies to eliminate them.

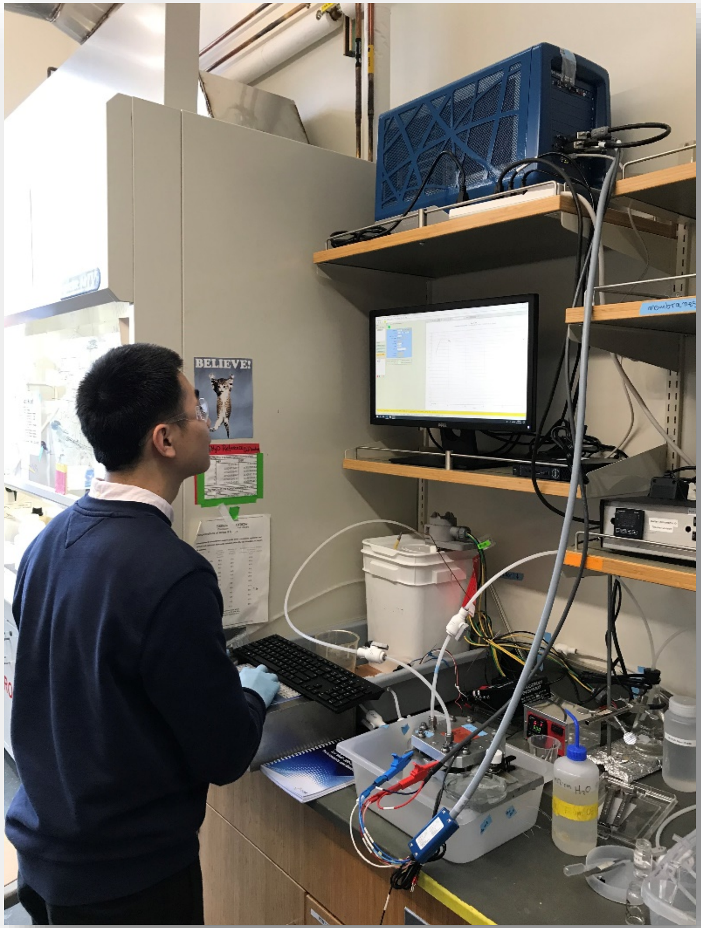
Grace Lindquist

Dr. Sebastian Oener (DFG Fellow)



Approach - Innovation

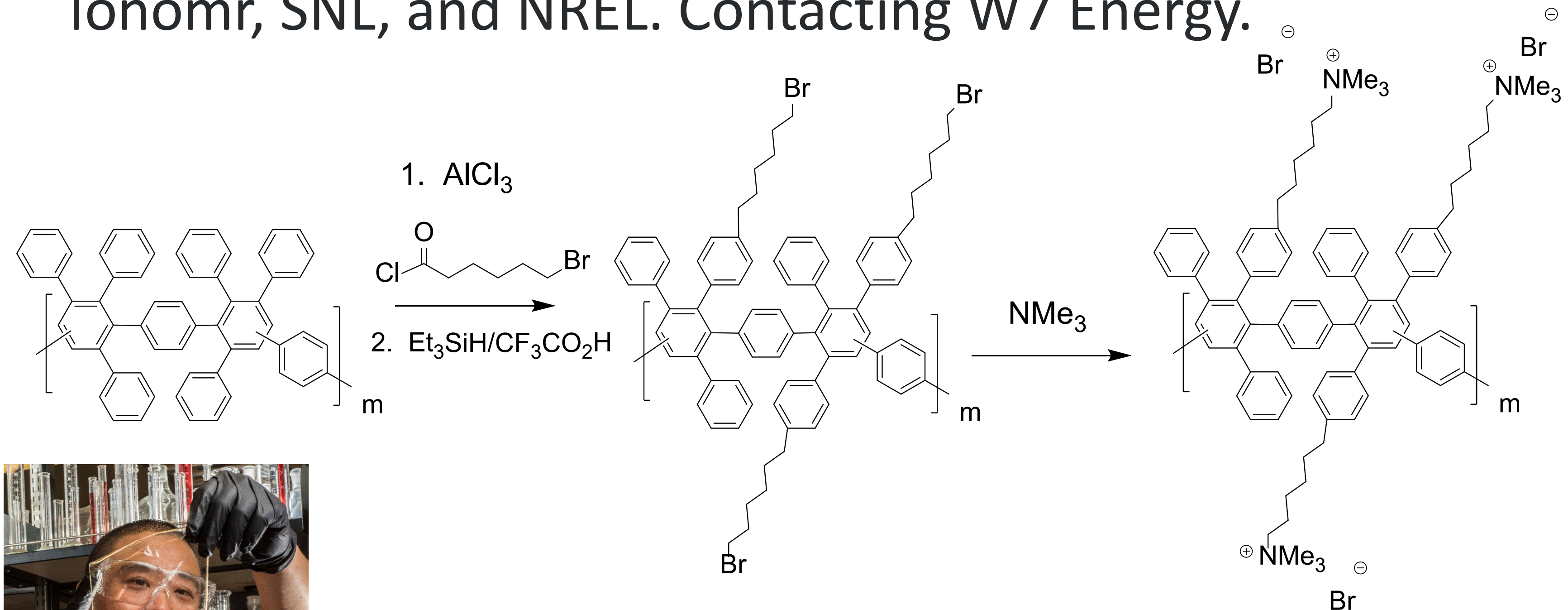
- In the first budget period we are:
  - building a new test station
  - validating benchmark processes and devices
  - demonstrating initial performance standards in varying water quality



4 cm^2, temperature and flow control, impedance, up to 10 A, computer controlled, low cost

Approach - Innovation

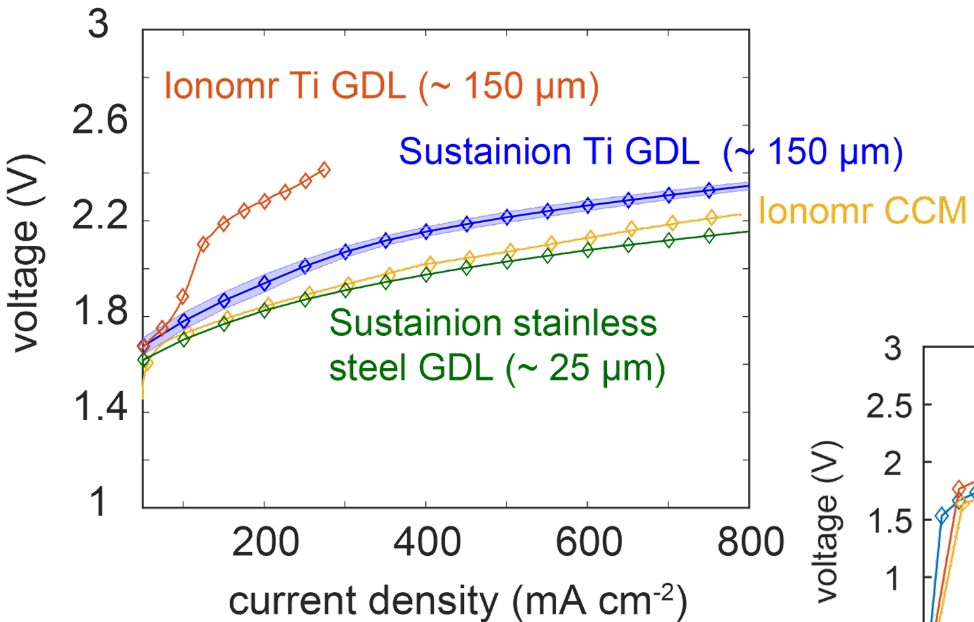
- We have state of the art AEM membranes from Sustainion, Ionomr, SNL, and NREL. Contacting W7 Energy.

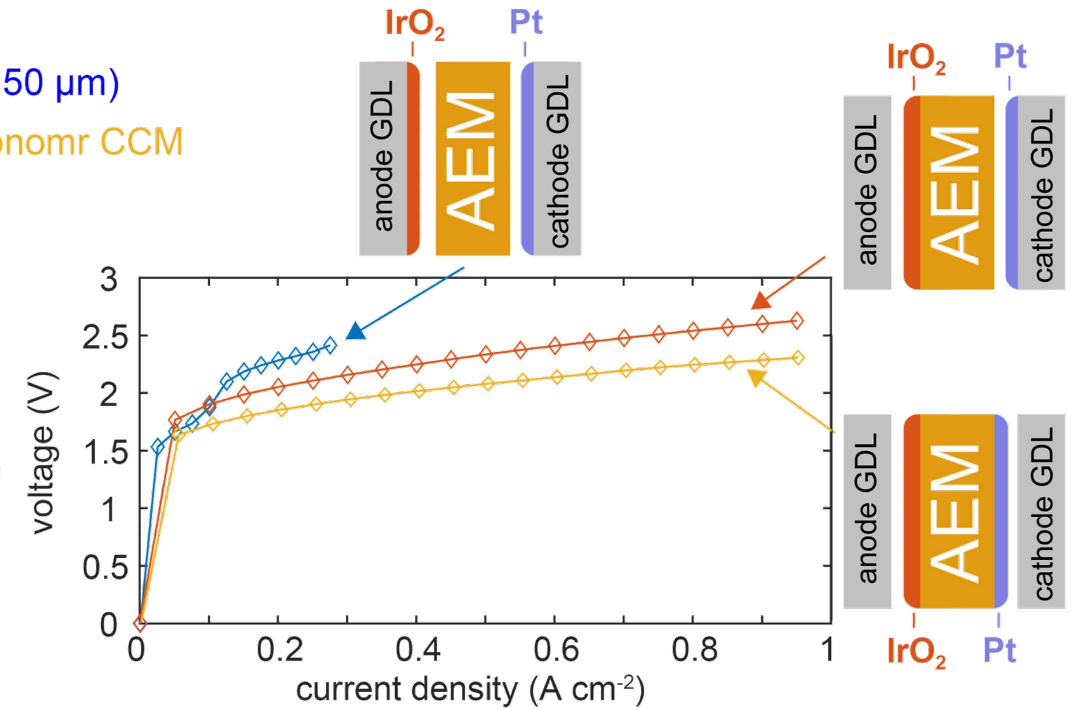


Dr. Cy Fujimoto

Accomplishment - Baseline electrolyzers

- Our project has not yet officially started, but we have started working to develop robust reliable AEM/BPM baseline electrolyzer performance in pure water.



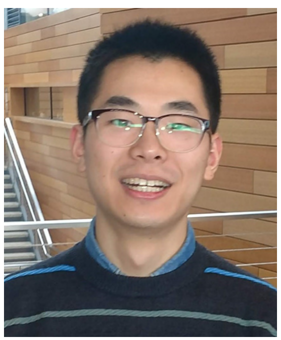


Accomplishment - Short term stability

Anode

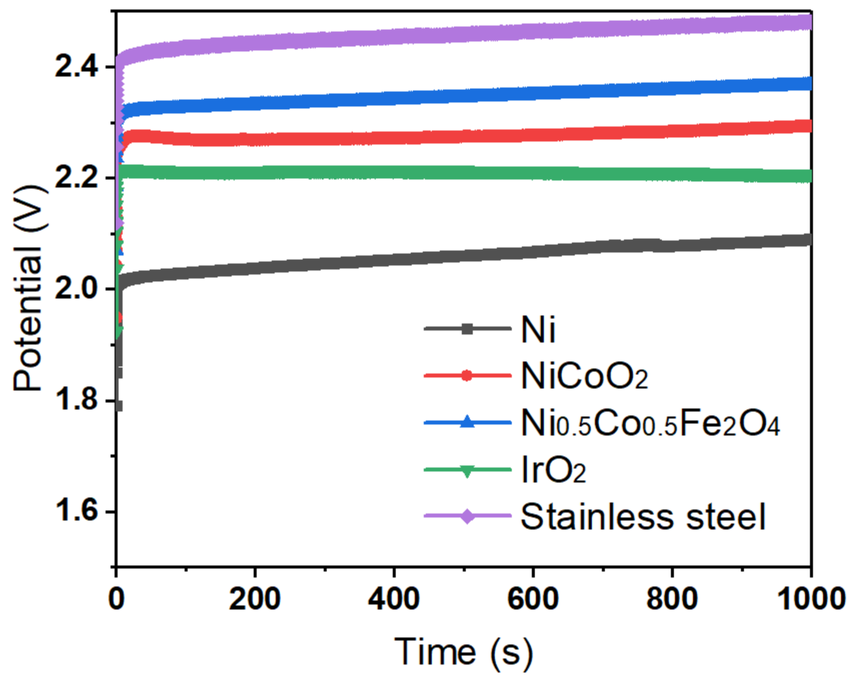
MO_x on Ti
Sustainion membrane
Pt on Toray C

Cathode



Qiucheng Xu
(CSC Fellow)

0.5 A cm^{-2} stability test

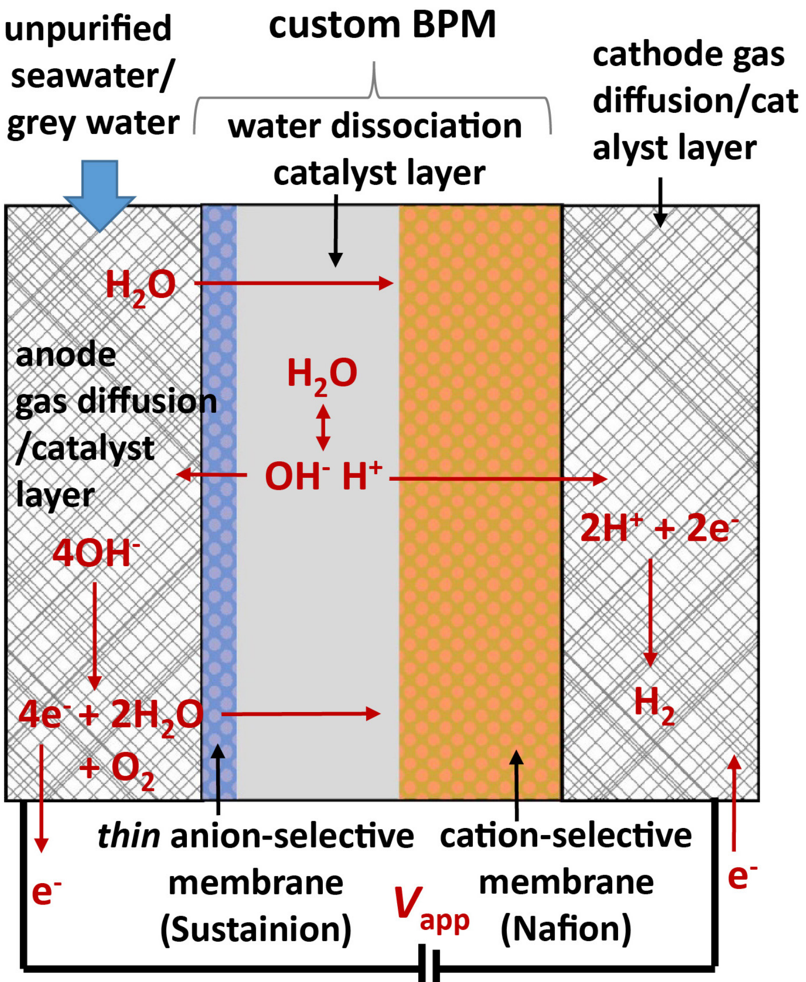


Why do non-precious metal OER catalysts degrade so fast?

Ionomer degradation or catalyst degradation?

Approach - Innovation

- We will work to control ion flow in AEM and BPM electrolyzer architectures and understand degradation modes and strategies to eliminate them.

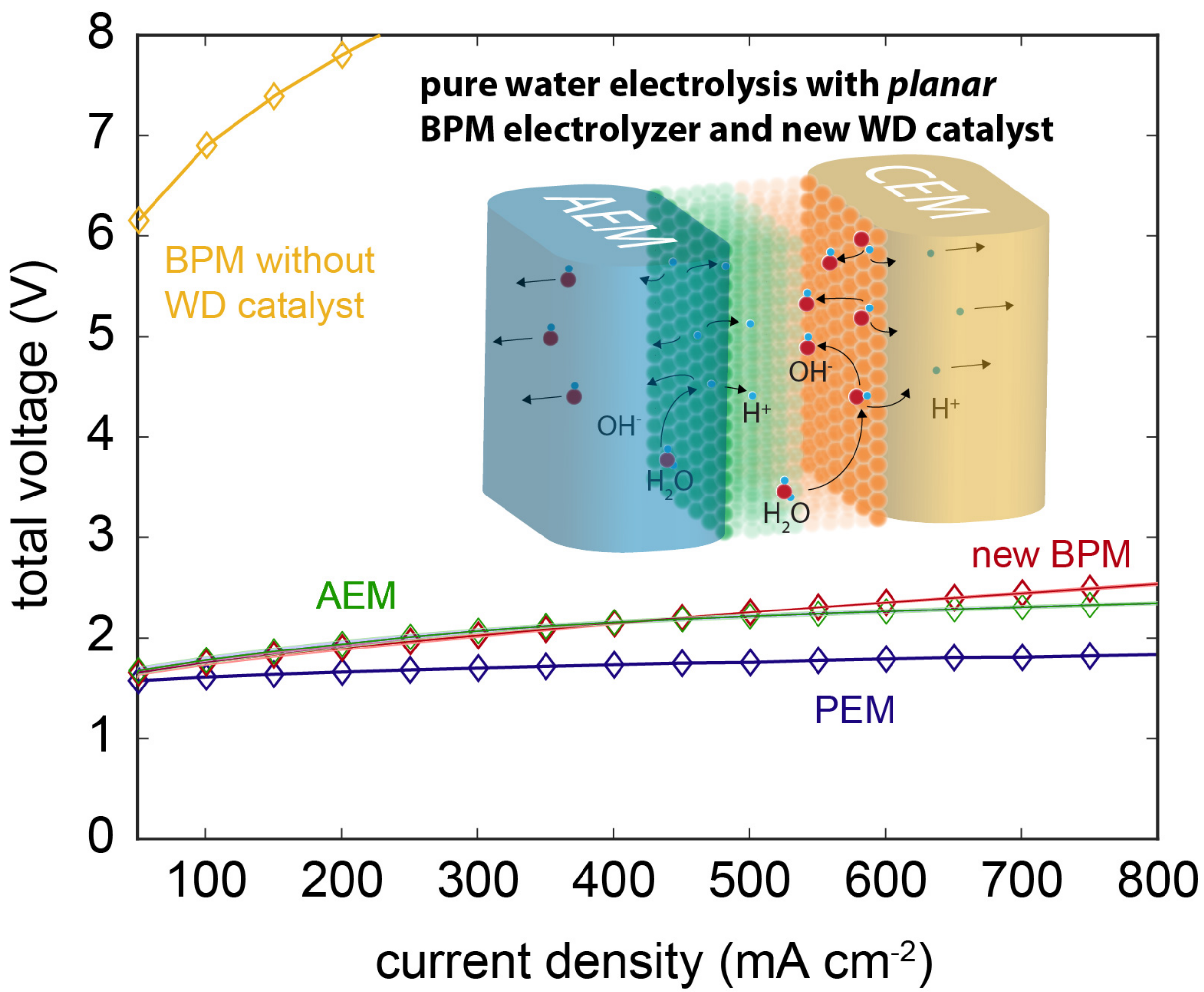


Grace Lindquist

Dr. Sebastian Öener (DFG Fellow)

Accomplishment - BPM electrolysis

- We have constructed world-record bipolar membranes by studying and controlling the water dissociation reaction.



Oener, Foster, Boettcher, 2020 not yet rejected from *Science*.

Collaboration: Leveraging of the EMN Resource Nodes

- LBNL Nodes
  - Weber: Develop robust numerical simulations (COMSOL) to better understand function in pure and dirty water.
  - Kusoglu: Quantitative measurements of hydration in the membrane and multi-ion partitioning under equilibrium and steady state
  - Danilovic: Engineer/understand ink formulations
- NREL Nodes
  - Alia: Transfer best practices for fabrication and benchmarking
  - Pivovar: AEM membranes and device optimization
- SNL Node
  - Fujimoto: New membrane and ionomer chemistries

Remaining Challenges

- Develop robust baseline for AEM electrolysis in pure water leveraging learning on pure water degradation modes particularly alkaline ionomer oxidative stability and interplay with catalyst
- Need comprehensive computational model to understand ion partitioning and transport in AEM and BPM operation with dirty water
- Need to understand, quantify and ideally eliminate degradation modes in impure water including
  - Tap water
  - Grey water
  - Seawater

Future work for next year

- Generate critical foundational knowledge on the operation of AEMs in pure water. *One technical goal is to demonstrate AEM electrolyzers that have performance near that of PEM electrolyzers when fed with pure water provide durable operation.*
- Feed the “dirty” water to the anode side of an AEM electrolyzer. Understand *mechanisms to affect membrane-fouling rates. The technical target will be to achieve < 0.1 mV/h stabilized fade after the first 18 months of development.*
- Characterize the various degradation modes iteratively tuning membrane, catalyst, and ionomer properties to improve durability and performance. Advanced characterization techniques including cross-sectional and 3D imaging and chemical analysis, electrochemical and impedance analysis, and computer modelling will all be employed to follow/understand the critical processes

Technology Transfer Activities

- None to date.
- PhD students completed internship at Proton OnSite / NEL Hydrogen facilitating academic/industry cooperation.

Summary

- Project very recently started. We have started work on pre-award spending and are waiting on DOE funds.
- Excellent progress toward both good baseline AEM performance and understanding of durability issues. Strategy to address those will be implemented up lab re-opening.
- Strong foundational performance in BPM pure water electrolysis
- HydroGEN partnerships working already with collaborations on ionomer membranes and simulation already started.