Electrochemical Conversion of Carbon Dioxide to Alcohols (FE0029868)

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UNIVERSITY OF DELAWARE

Project Funding: $1,000,000 ($800,000 DOE share; $200,00 UD Share)

Budget Period 1: 06/01/2017-11/30/2018

Budget Period 2: 12/01/2018-05/31/2020

	Budget Period 1 06/01/2017 - 11/30/2018		**Budget Period 2 12/01/2018 - 05/31/2020**		**Total Project**	
	Government Share	Cost Share	Government Share	Cost Share	Government Share	Cost Share
Applicant	$421,099	$105,275	$378,901	$94,725	$800,000	$200,000
Total	$421,099	$105,275	$378,901	$94,725	$800,000	$200,000
Cost Share	80%	20%	80%	20%	80%	20%

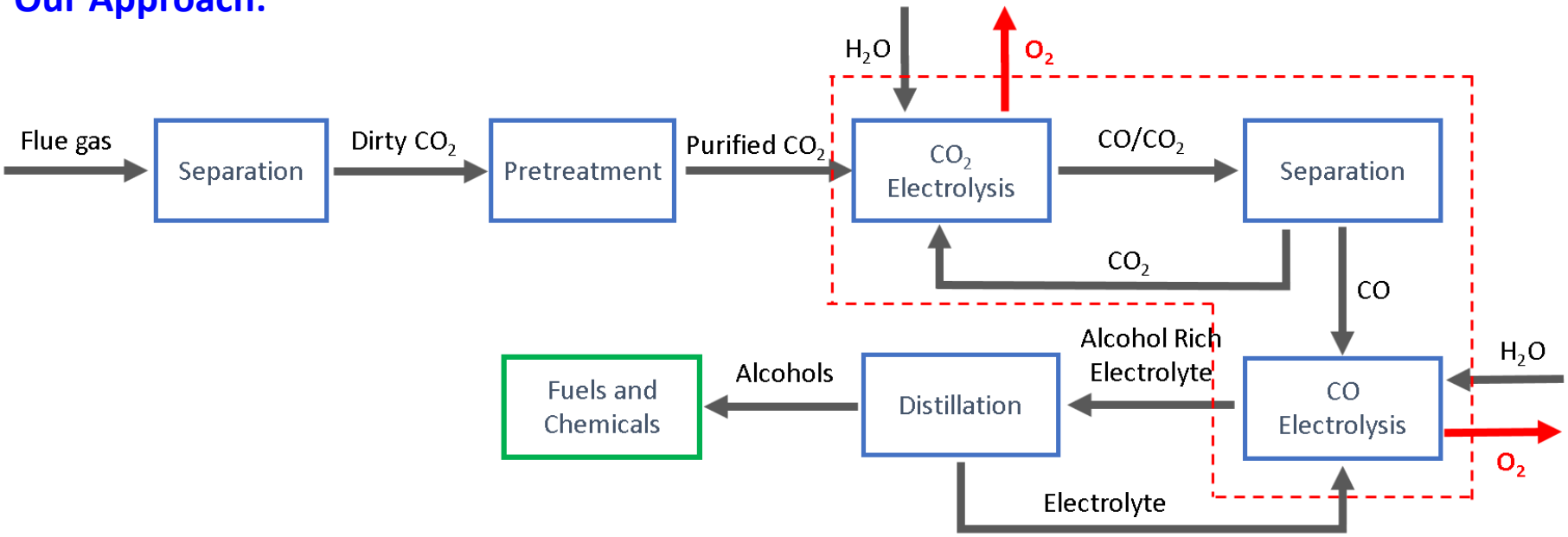
Project was officially launched on June 1st, 2017.

Kick-off meeting was held on July 10th, 2017.

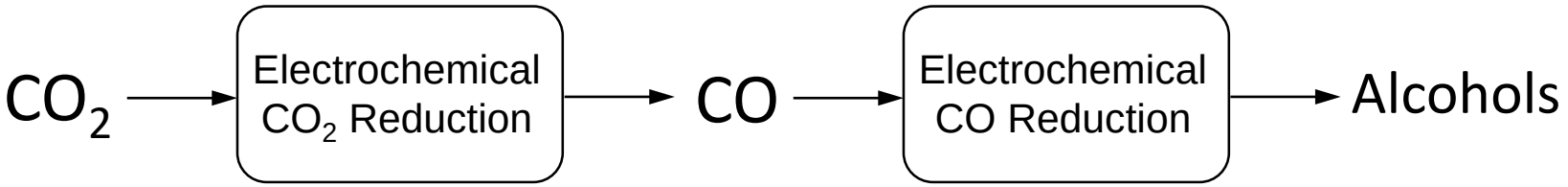
Project Objectives and Approach

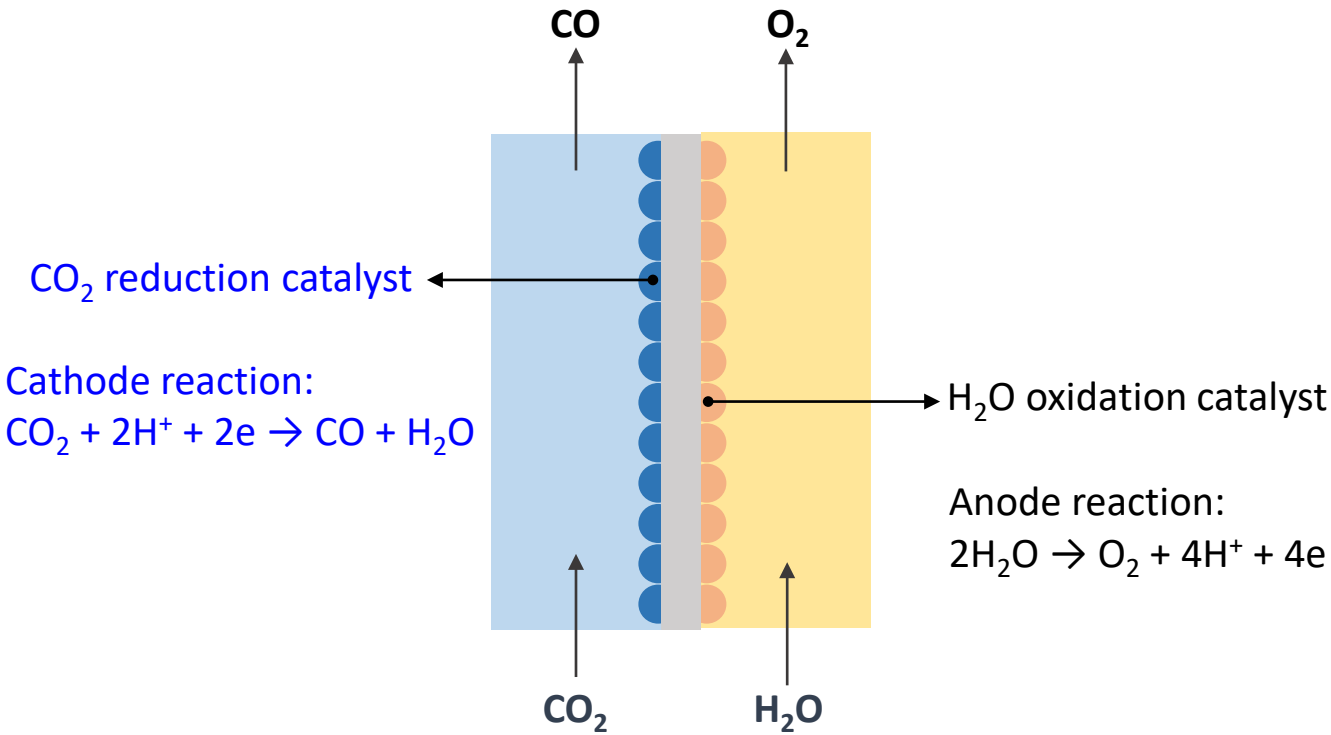
1) Development of critical components for an electrochemical system that is able to convert CO_2 into C_2/C_3 alcohols
2) Demonstration of key functions of an integrated electrochemical system for CO_2 conversion using flue gas from coal-fired power plants
3) Full analysis of economics and life-cycle of the CO_2 electrolysis technology for CO_2 emissions mitigation from coal-fired power plants

Our Approach:



Proposed Two-stage Process and its Chemistry

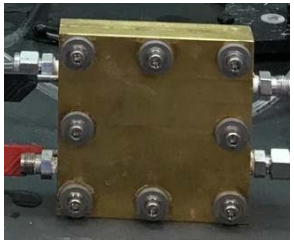




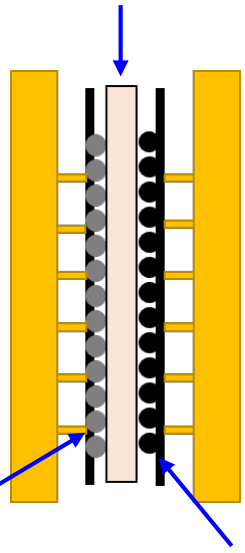
CO_2-to-CO Electrolyzer: major accomplishments (1)

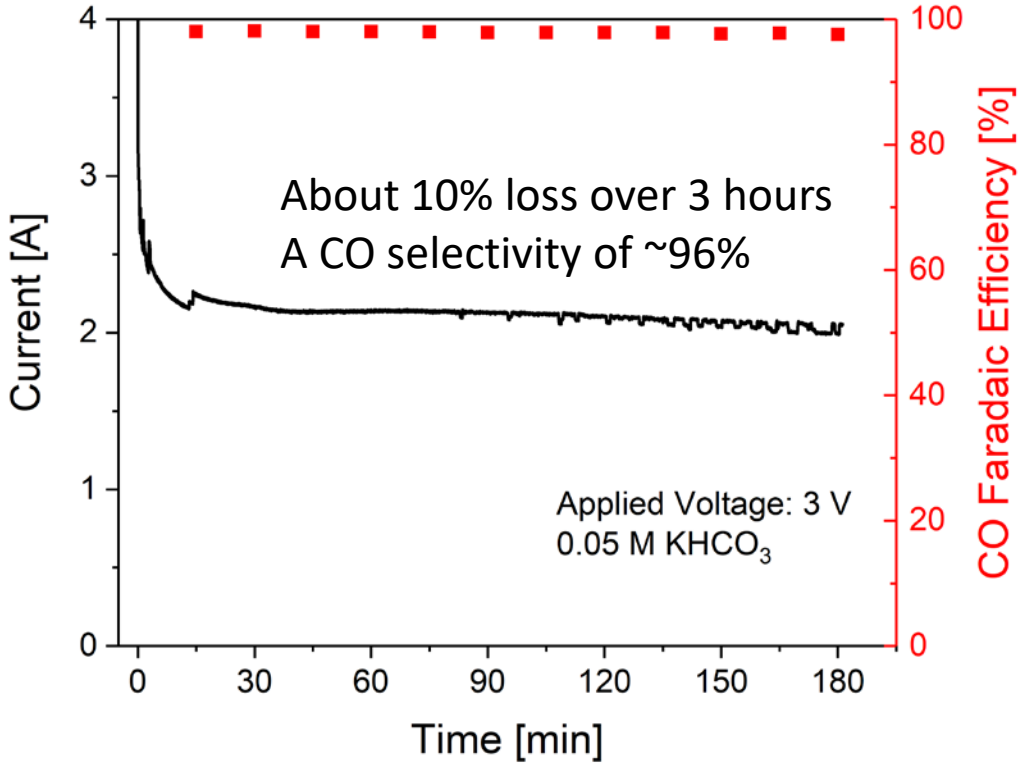
Target:

Single cell potential <3 V, a total current of >5 A, CO selectivity >70%, 3 hour stability (<20% loss).



Single cell setup





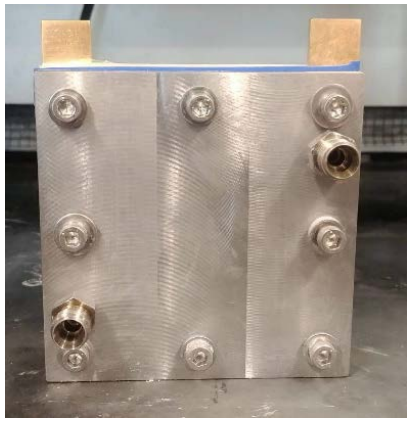
A multi-cell stack is required to meet the current target (5A, production rate).

CO_2-to-CO Electrolyzer: major accomplishments (2)

Scale up from a single cell to a stack of 4 cells

Two designs are currently under investigation:

- Bipolar design – cells in series
- Parallel design – cells in parallel (*under testing*)

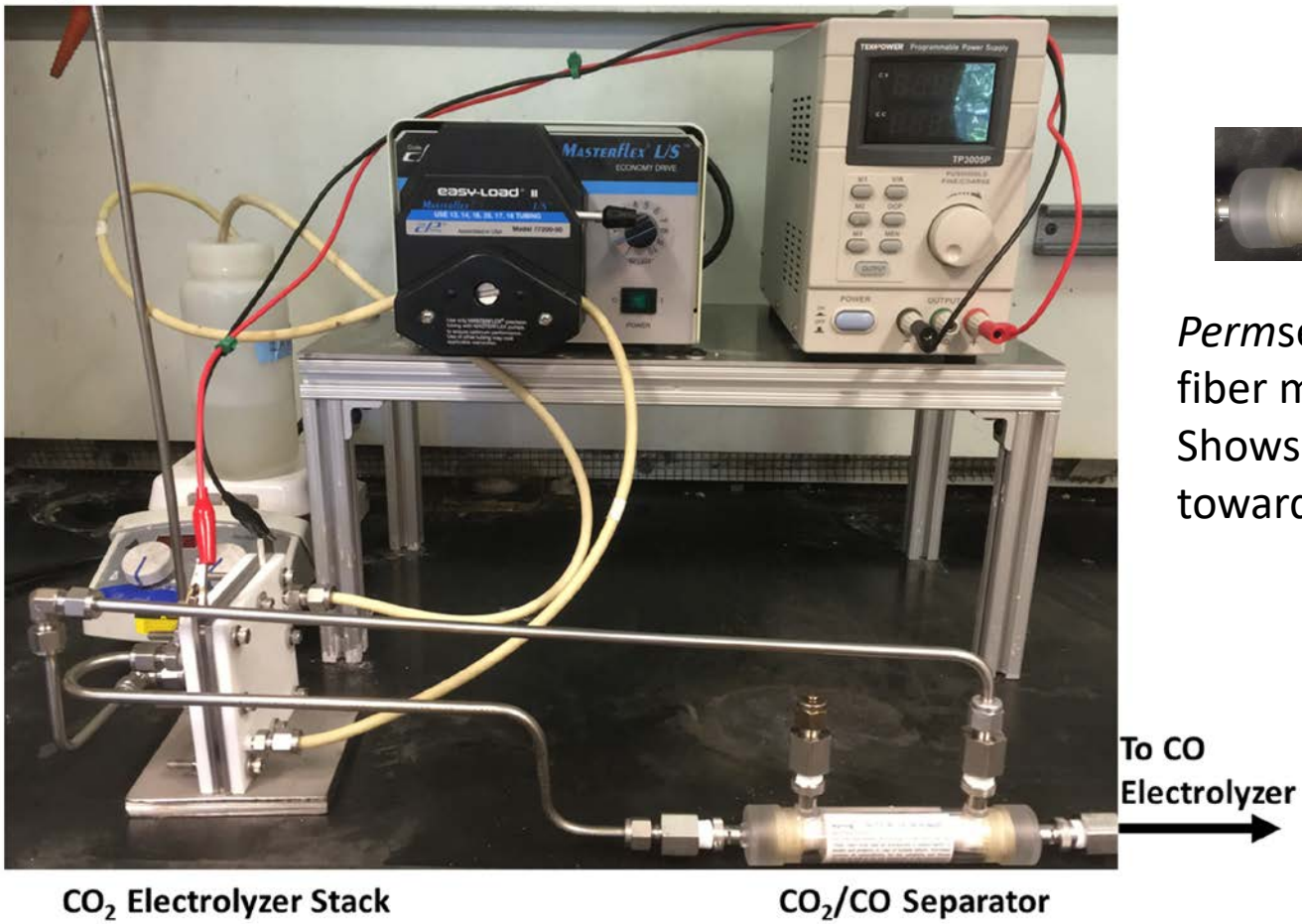


	Voltage [V]	Current [A]
Cell 1	3.02	2
Cell 2	2.82	2
Cell 3	2.98	2
Cell 4	2.98	2
Total (in series)	**11.8**	**2**

This is equivalent to 3V(each cell) at a total current of 8A when cells are connected in parallel.

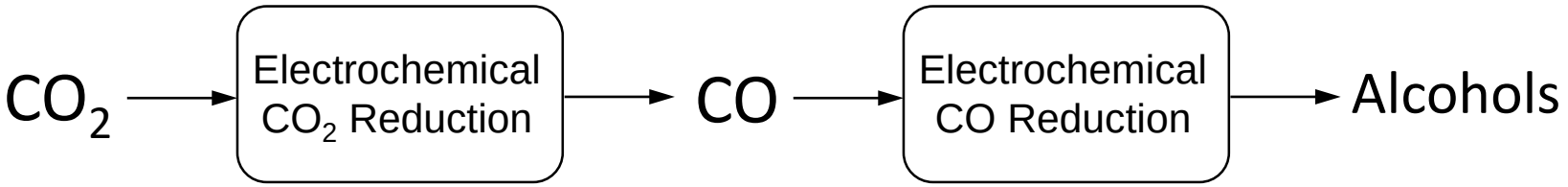
CO_2-to-CO Electrolyzer: major accomplishments (3)

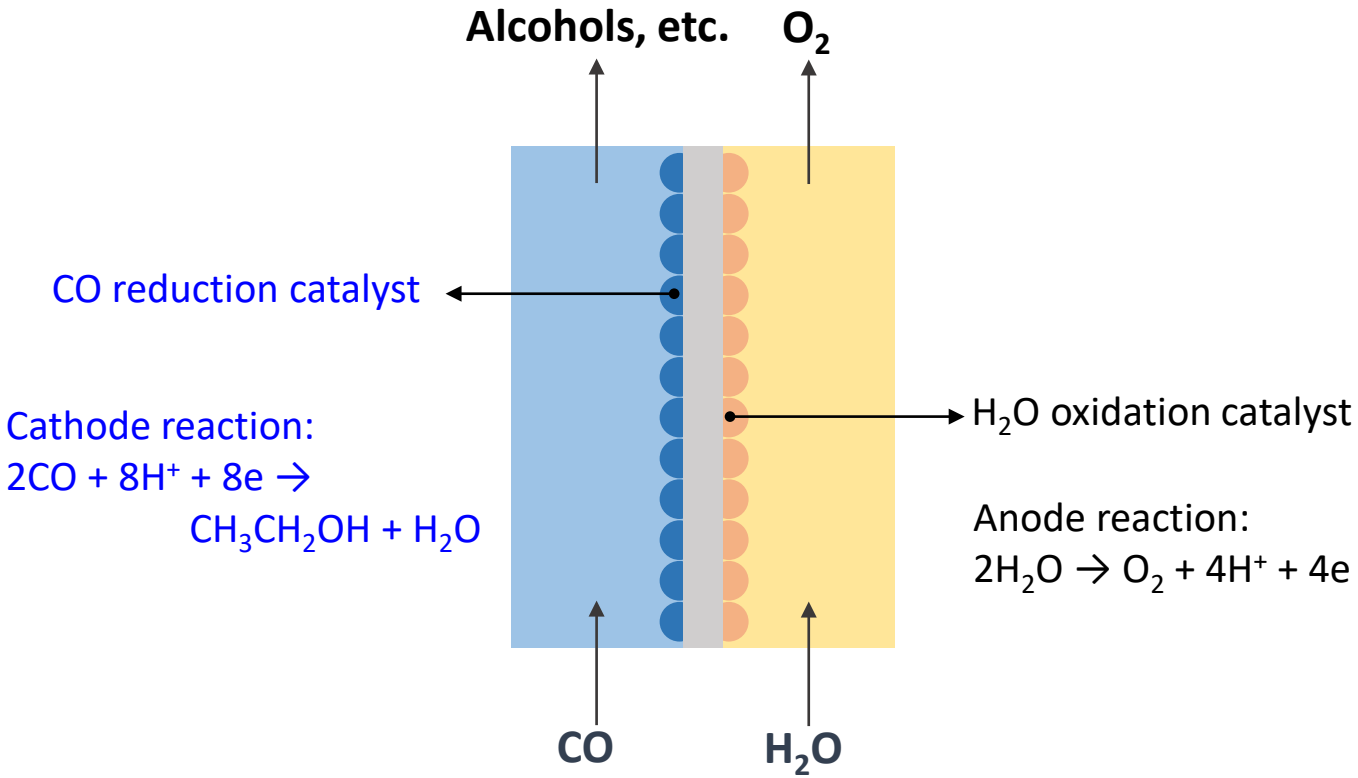
CO_2 Electrolyzer subsystem



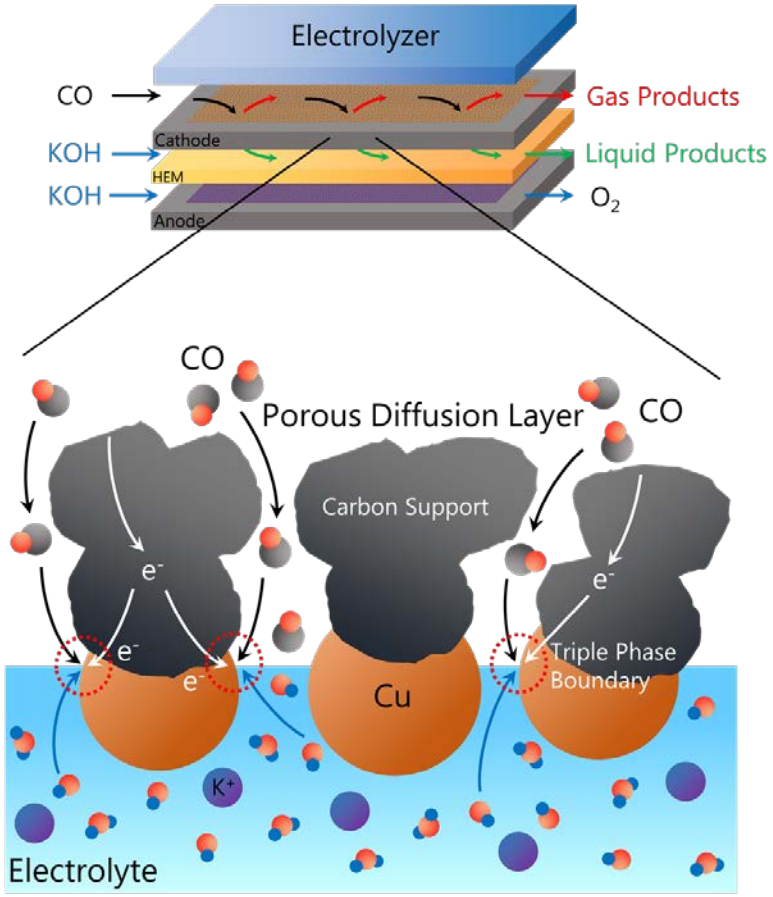
*Perm*select silicone hollow fiber membrane module: Shows promise for selectivity towards CO_2

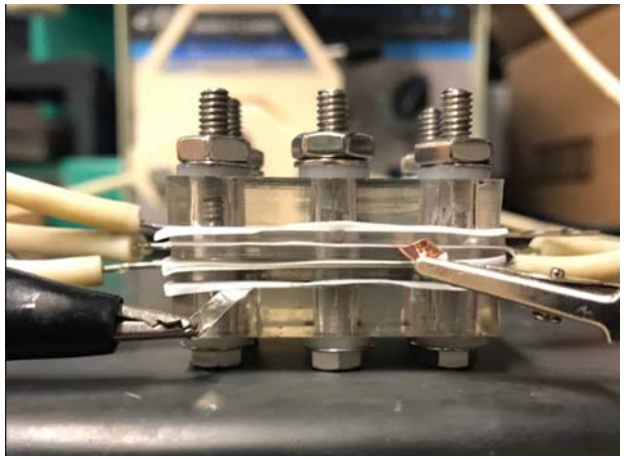
Proposed Two-stage Process and its Chemistry

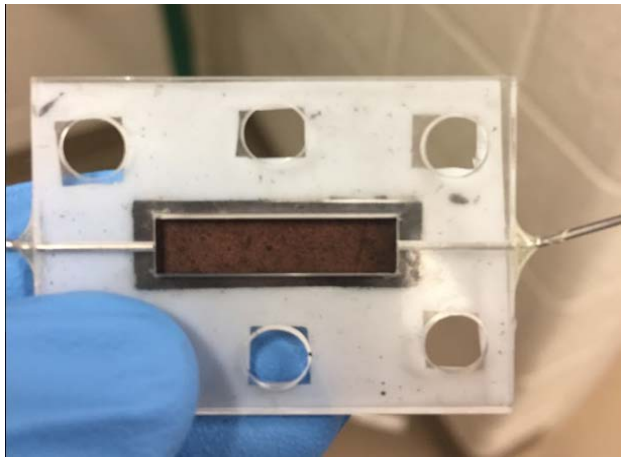




CO-to-C_{2+} Electrolyzer: major accomplishments (1)

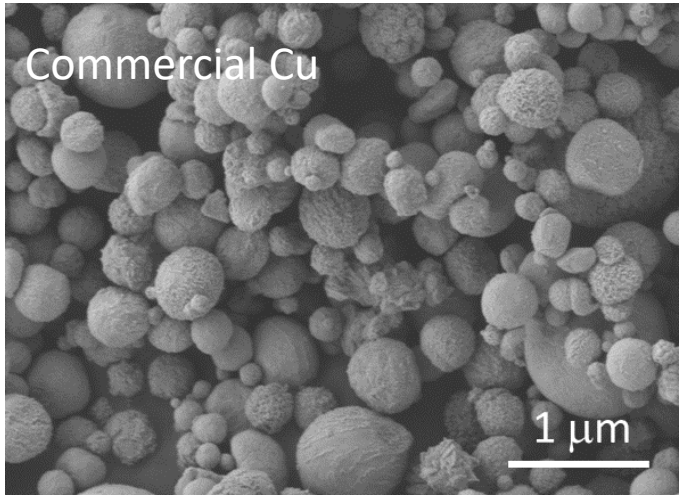






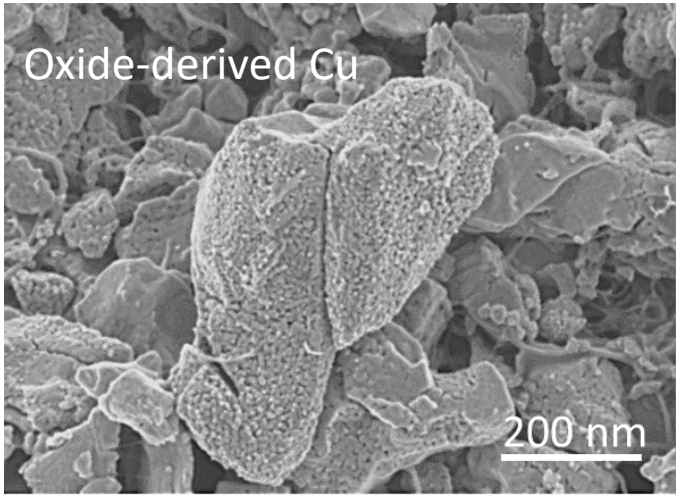
- Design of microfluidic electrolyzer with a well-controlled gas/liquid interface

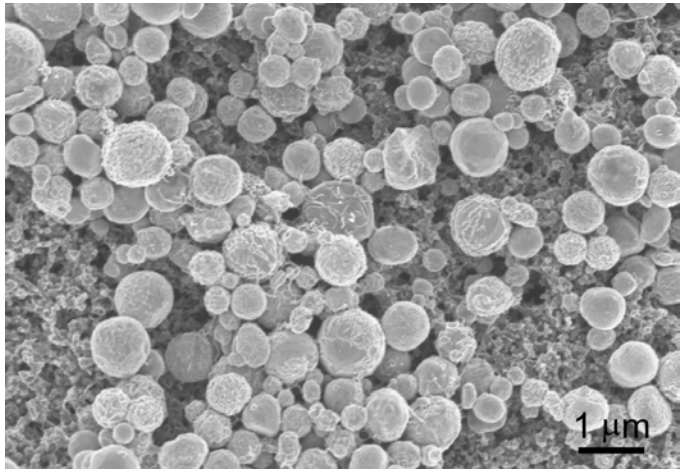
CO-to-C_{2+} Electrolyzer: major accomplishments (2)



500 °C

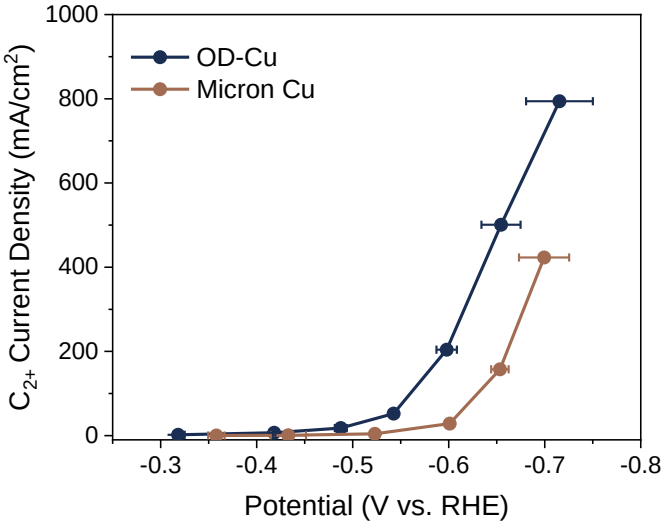
In-situ reduction

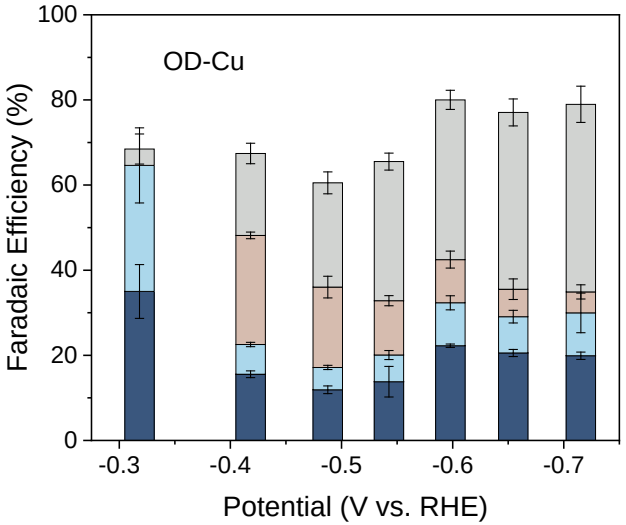


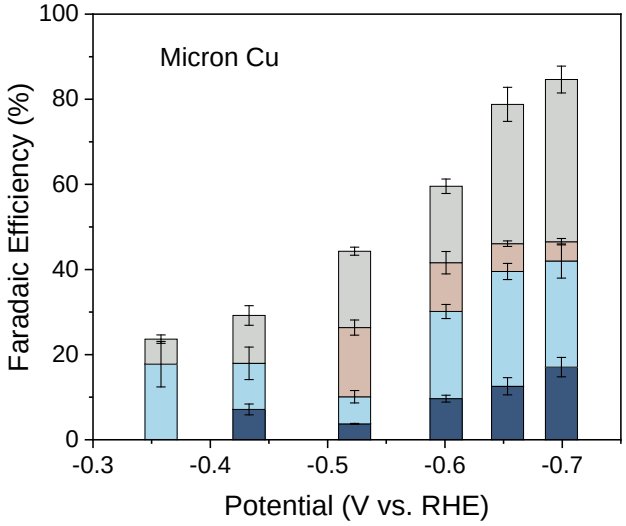


- Synthesis of nanostructured oxide-derived copper catalyst
- Previous batch-cell testing showed up to 45% alcohol Faradaic efficiency
- Assembly of catalyst-loaded gas-diffusion layer

CO-to-C_{2+} Electrolyzer: major accomplishments (3)





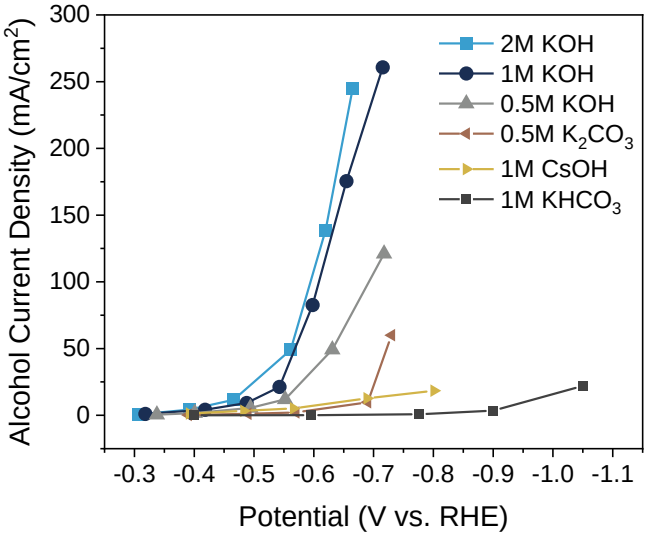


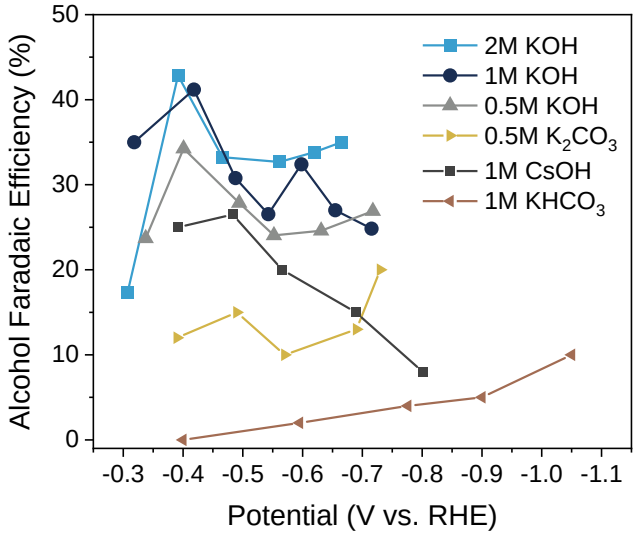
Ethylene n-Propanol Acetate Ethanol

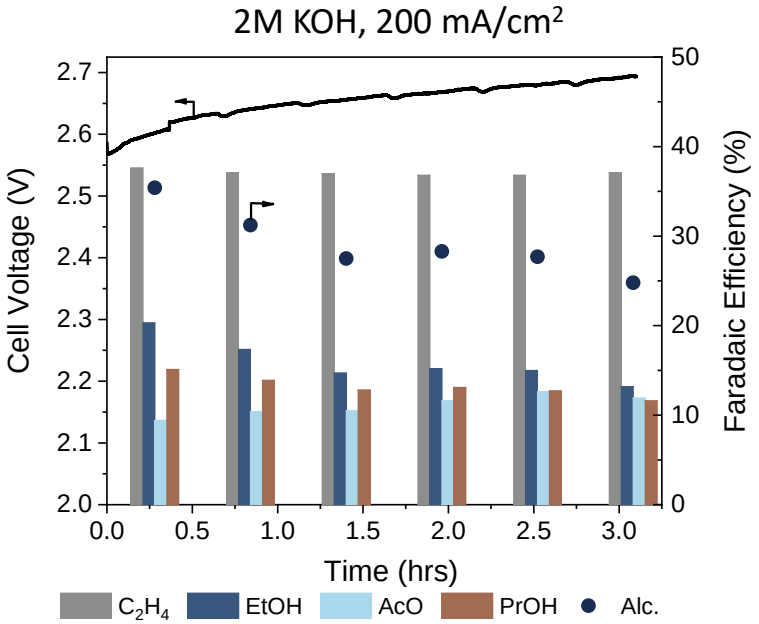
- OD-Cu shows enhanced oxygenate selectivity at low overpotentials.
- C_{2+} product selectivity >80% at current densities up to 1 A/cm^2.

Jouny, Luc, Jiao, *Nature Catalysis* (in press). DOI: 10.1038/s41929-018-0133-2.

CO-to-C_{2+} Electrolyzer: major accomplishments (5)







- Electrolyte dependence study shows concentrated KOH provides optimal performance.
- Demonstration of 3 hrs. stability with minimal voltage increase.
- Ongoing work focused on maintaining alcohol production stability.

Project Schedule and Milestones

				Budget Period 1						Budget Period 2					
				06/01/2017-11/30/2018						12/01/2018-05/31/2020					
	Start Date	End Date	Cost	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Task 1.0 - Project Management and Planning	6/1/2017	5/31/2020	$50,000												
Milestones															
Milestone 1.a - Updated Project Management and Planning				X											
Milestone 1.b - Complete Kick-off Meeting				X											
Milestone 1.c - Complete Review Meetings						X			X		X		X		
Milestone 1.d - Complete Midterm Report										X					
Milestone 1.e - Complete Final Review Meeting															X
Milestone 1.f - Complete Final Report															X
Milestone 1.g - Complete Safety and Environmental Analysis						X			X			X			
Task 2.0 - Development of CO_2 Electrolyzer Subsystem	6/1/2017	11/30/2018	$250,000												
Milestones															
Milestone 2.a - Complete the Conceptual Design of CO_2 Electrolyzer				X											
Milestone 2.b - Complete the Development of Electrocatalysts					X										
Milestone 2.c - Complete the Development of Contactor and Separator						X									
Milestone 2.d - Complete the Fabrication of CO_2 Electrolyzer Subsystem							X								
Milestone 2.e - Complete the Evaluation of CO_2 Electrolyzer Subsystem								X							
Milestone 2.f - Complete the Evaluation of Alternative CO_2 Electrolyzer Design									X						
Task 3.0 - Development of CO Electrolyzer Subsystem	6/1/2017	11/30/2018	$200,000												
Milestones															
Milestone 3.a - Complete the Conceptual Design of CO Electrolyzer				X											
Milestone 3.b - Complete the Fabrication of CO Electrolyzer Subsystem								X							
Milestone 3.c - Complete the Evaluation of CO Electrolyzer Subsystem									X						

Green: completed Blue: on going

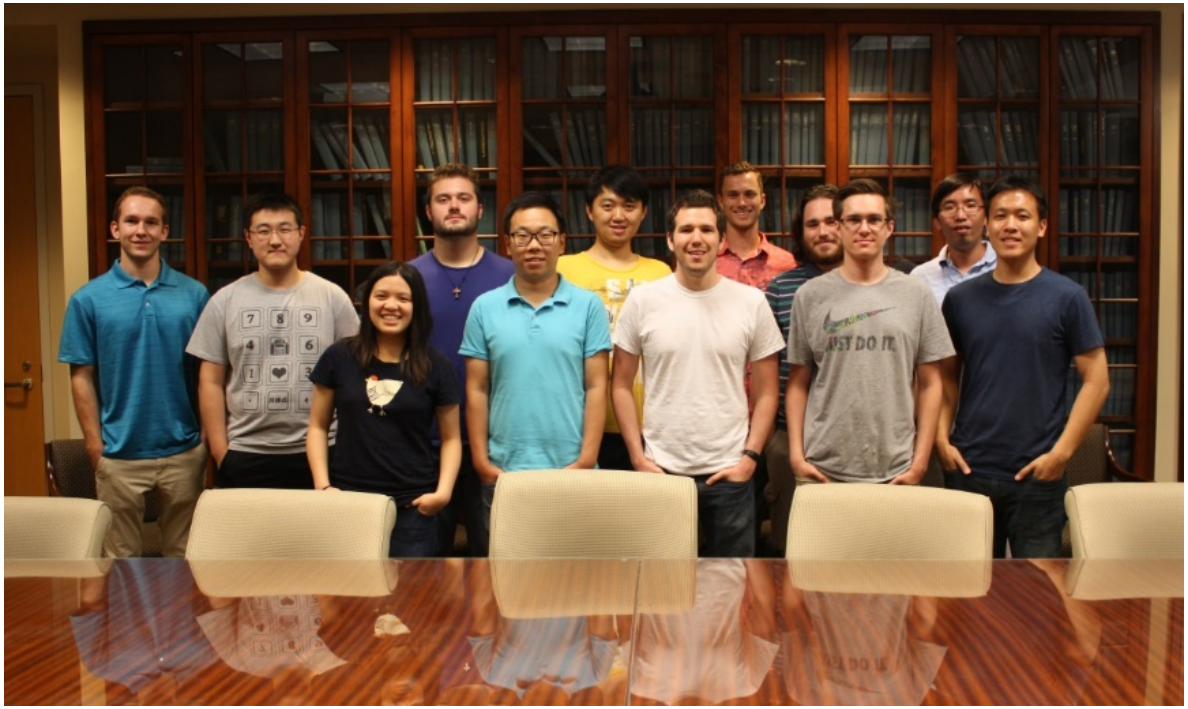
Testimony at the US Senate committee

On April 11, 2018, the PI testified before the Senate Committee on Environment and Public Works chaired by U.S. Senator John Barrasso and Senator Tom Carper.

The purpose of this hearing is to examine S. 2602, the Utilizing Significant Emissions with Innovative Technologies Act (or USE IT Act). The bill covers important research and investments on carbon capture and utilization technologies, including direct air capture, carbon utilization, and infrastructure.

This project was discussed at the hearing to emphasize the importance of developing new carbon utilization technologies.

Acknowledgements



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Thank you