Electrochemical Conversion of Carbon Dioxide to Alcohols (FE0029868)

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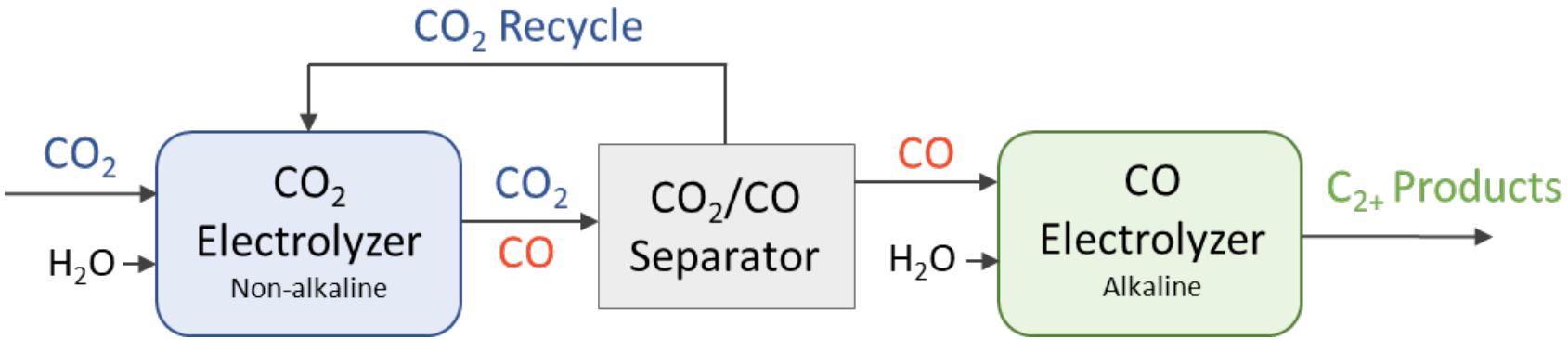
Project Objectives and Approach

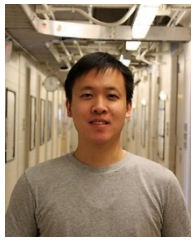
1) Development of critical components for an electrochemical system that is able to convert CO_2 into C_2/C_3 alcohols
2) Demonstration of key functions of an integrated electrochemical system for CO_2 conversion using flue gas from coal-fired power plants
3) Full analysis of economics and life-cycle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

Our Approach:



Project Team and Management


Matt Jouny


Wesley Luc


Emily Jeng


Brian Ko


Wenlei Zhu

Project Funding: $1M ($800k DOE share; $200k UD Share)

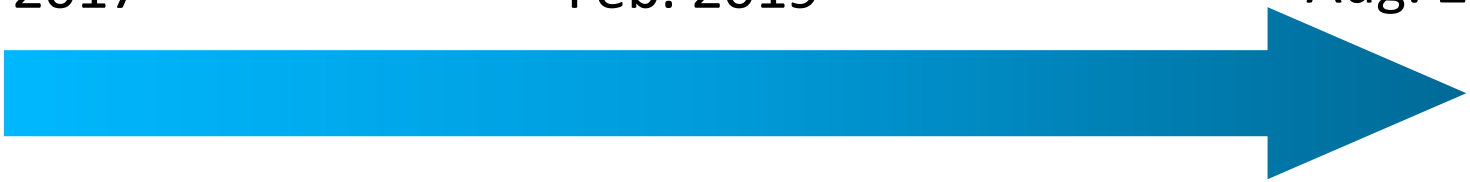
Budget Period 1: 06/01/2017-2/28/2019

Budget Period 2: 3/01/2019-08/31/2020

Kick off
Jun. 2017

Go/no-Go #1
Feb. 2019

Final Report
Aug. 2020

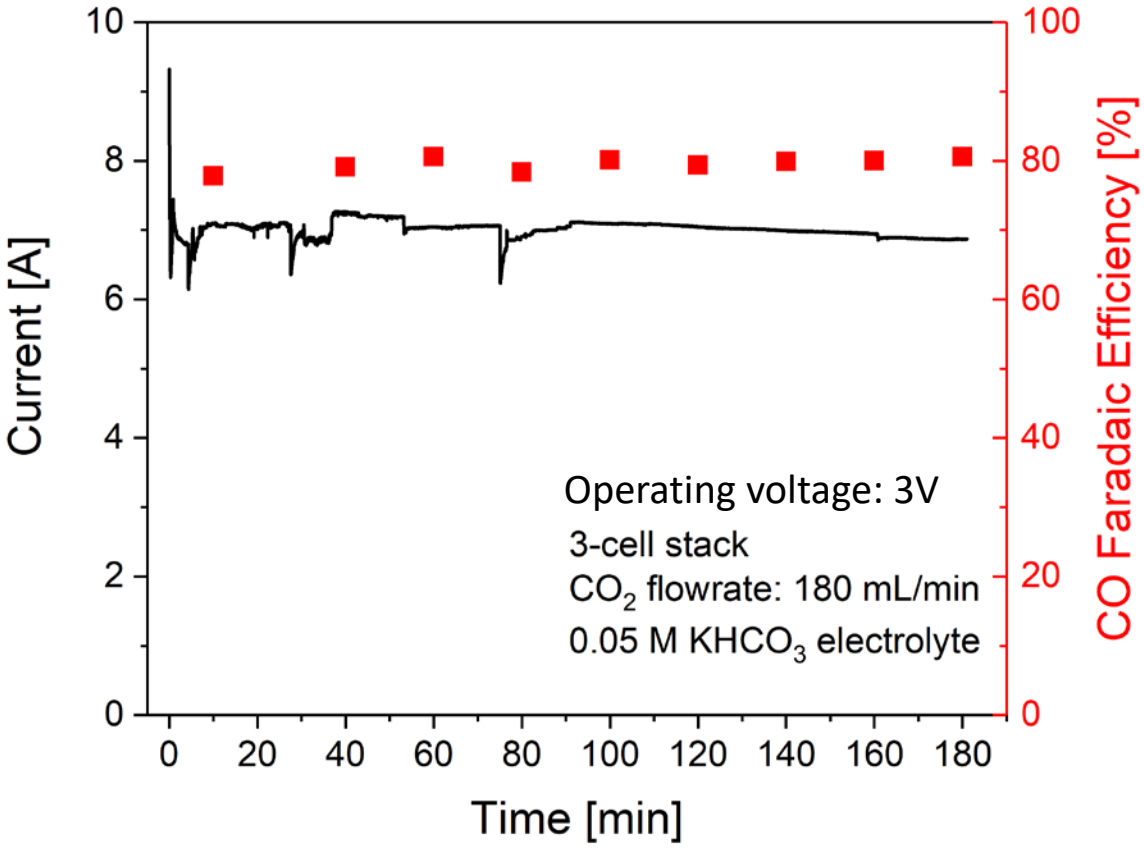


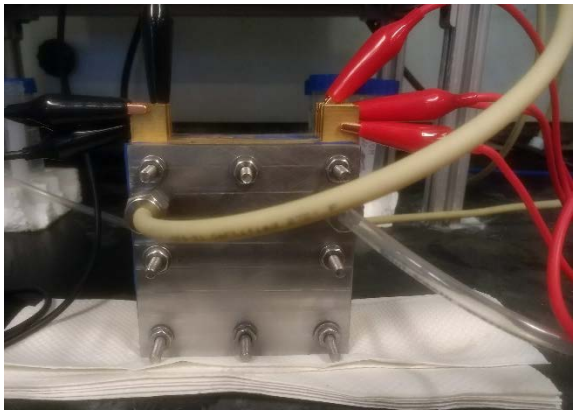
BP 1: Subsystem components development and evaluation

BP 2: System integration and evaluation, TEA, LCA

BP 1: CO_2 to CO Electrolyzer Stack

DOE BP1 Target: 3 V; 5 A; CO Faradaic efficiency: >70%; 3-hour stability (less than 20% loss)

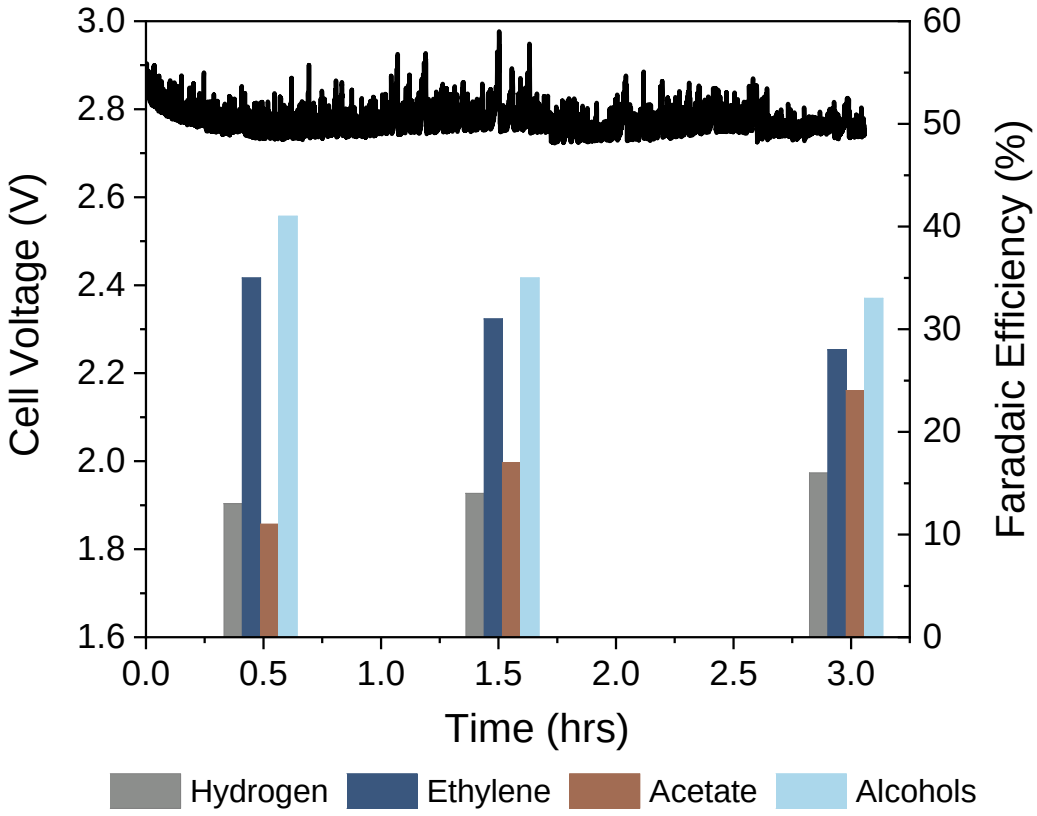


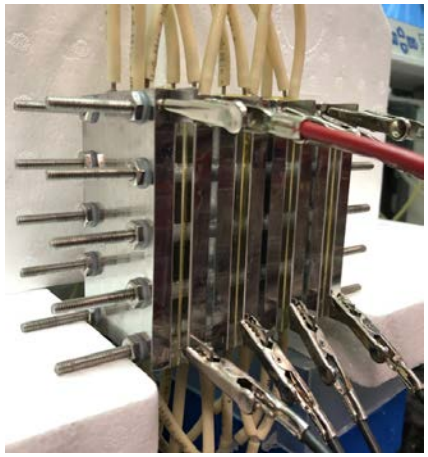


- A total current of ~7A was achieved at 3V
- Loss of current over 3 hours electrolysis is about 6%.

BP 1: CO to Alcohol Electrolyzer Stack

DOE BP1 Target: 3V; 10 A; 40% alcohol Faradaic efficiency, 3-hour stability (less than 20% loss)





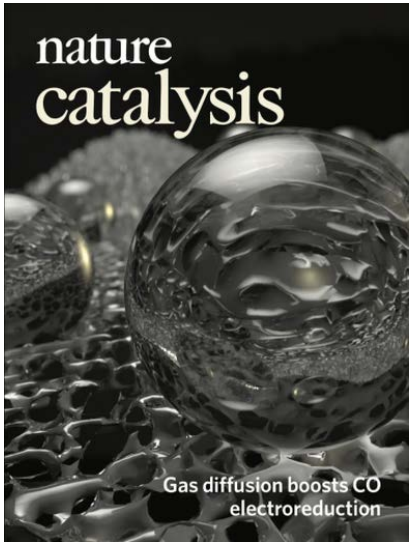
4 x 12.5 cm^2 (200 mA/cm^2), 2M KOH electrolyte, Cu nanoparticles as cathode (loading at 1.2 mg/cm^2), NiFe foam as anode

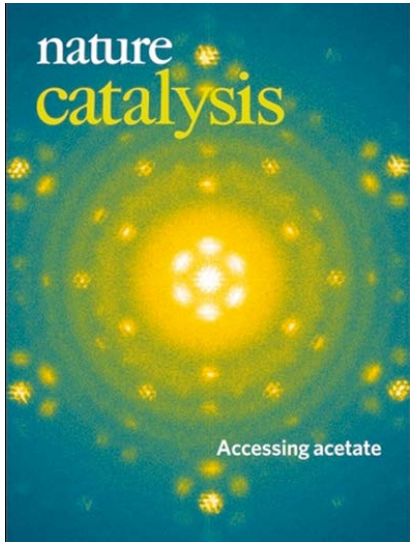
10 A at ~2.8 V
A total alcohol Faradaic efficiency of 40% was achieved with ~10% loss over 3 hours of operation.

M. Jouny, W. Luc, & F. Jiao, *Nature Catalysis* 1, 748-755 (**2018**).

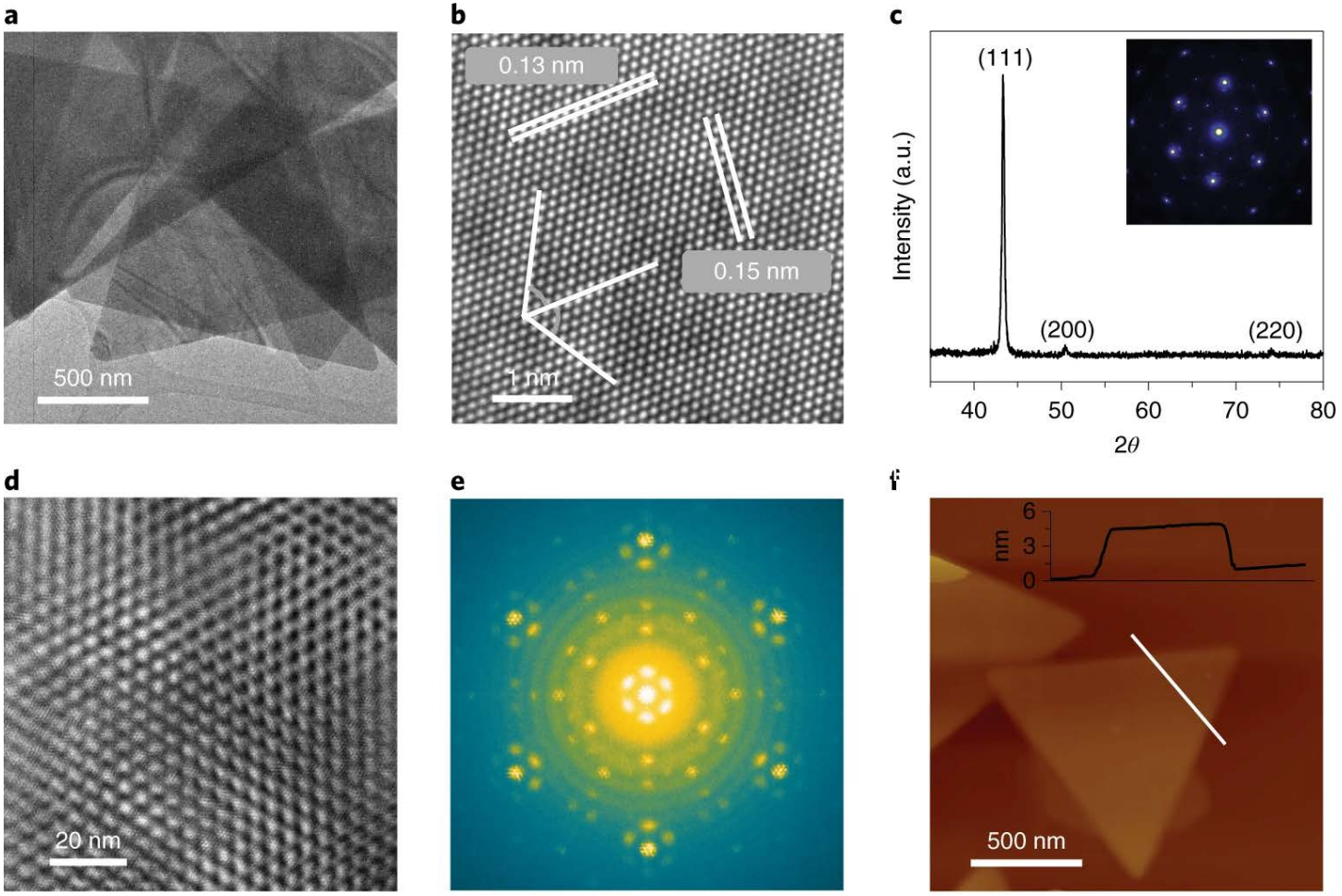
BP 1 achievements

- Met all the milestones and performance targets
- Published major results in leading scientific journals
- Filed an international patent application
- Testified before the US Senate Committee on USE IT Act (Chaired by Senate Barrasso)





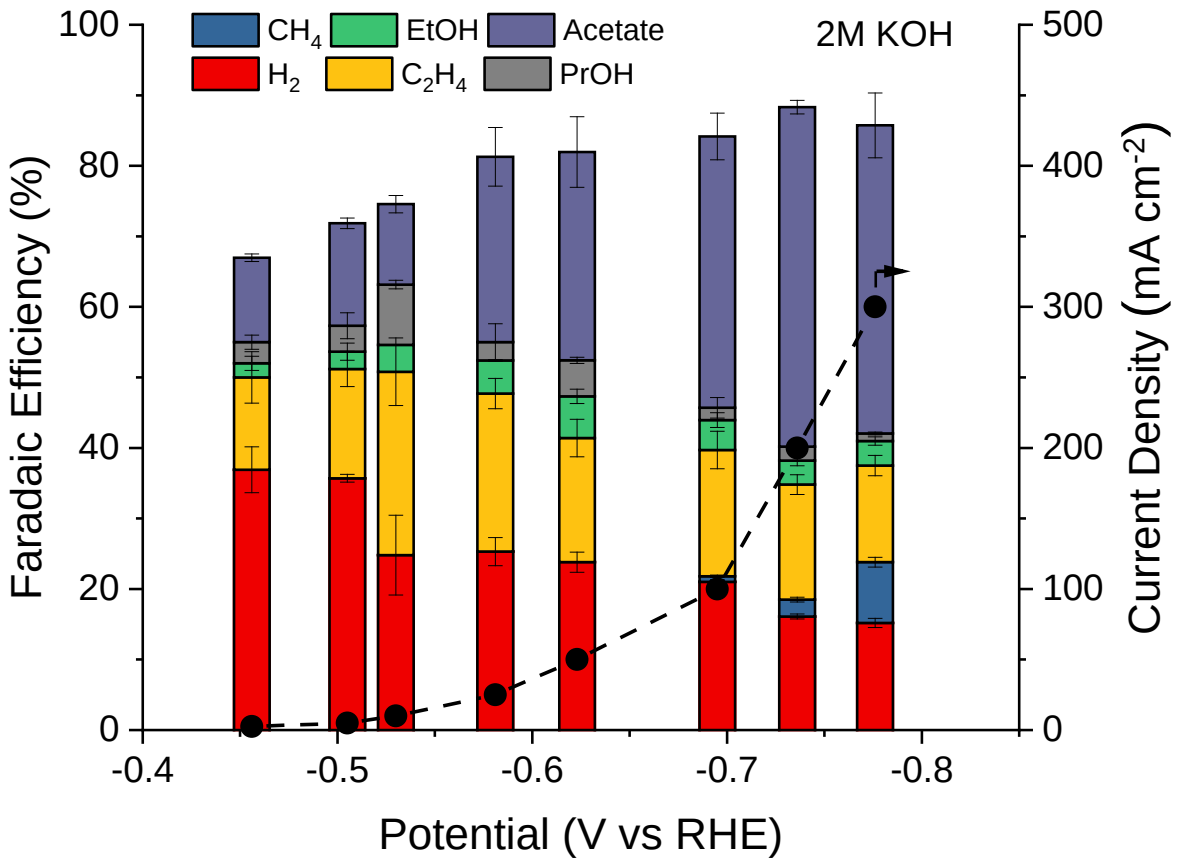
Two-dimensional Cu nanocatalyst



- Cu nanosheets with Cu(111) exposed were successfully synthesized
- Triangle shape (a few micron in dimension) and 4-5 nm in thickness

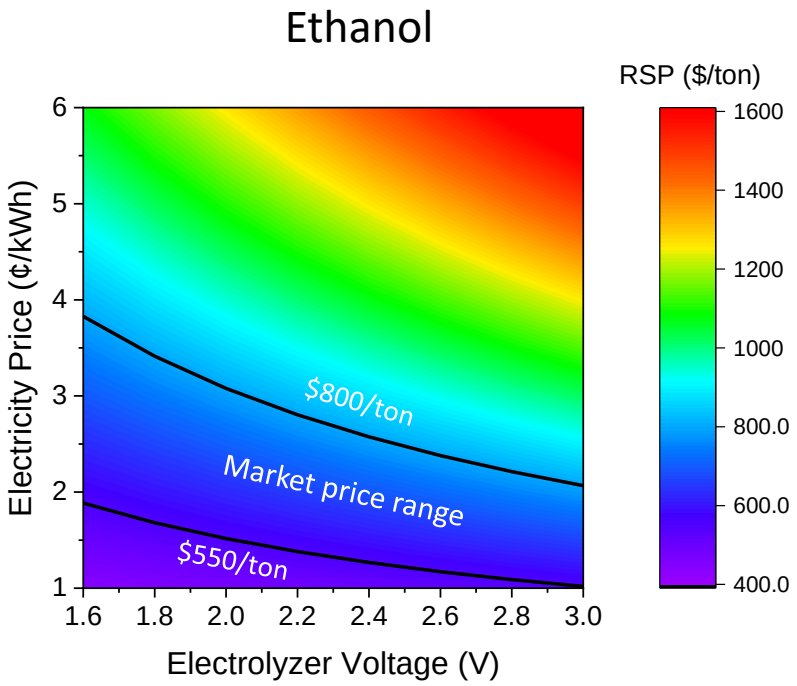
Jiao, et al. *Nature Catalysis* 2, 423-430 (**2019**).

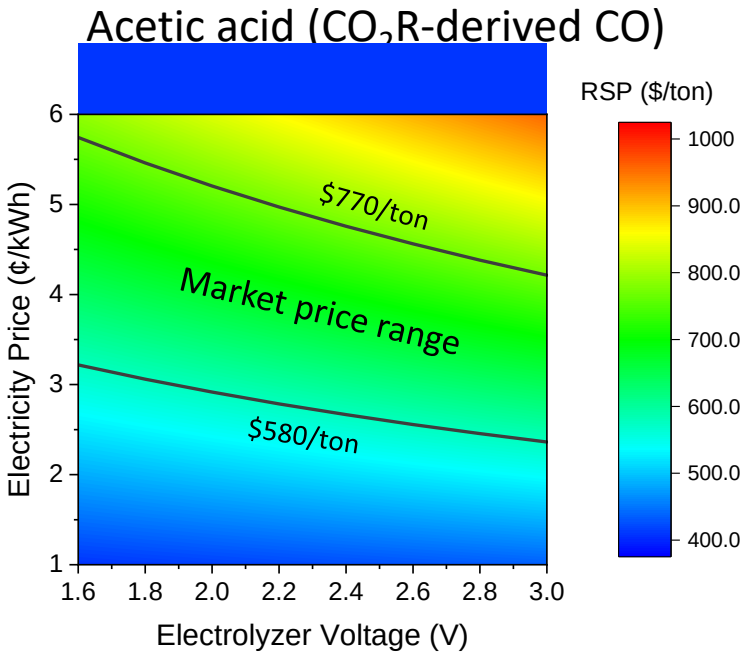
Electrochemical CO reduction to acetate



Cu(111) nanosheets exhibit a much higher acetate selectivity (up to 48%) than that of micron Cu and Cu nanoparticles (less than 25%).

Techno-economic analysis of CO_2 electrolysis



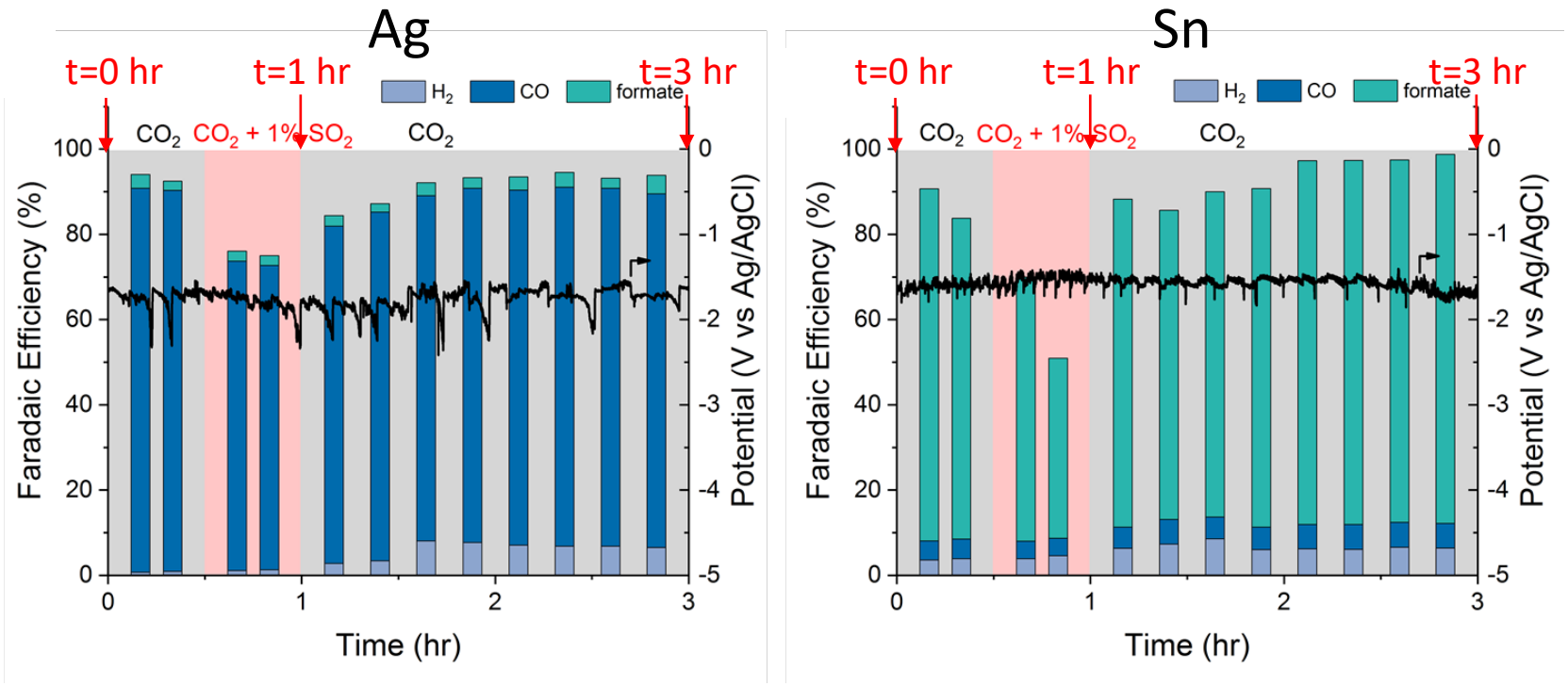


Critical Assumptions

- Electrolyzer Performance: 300 mA/cm^2, **90% selectivity**, 50% conversion
- Electrolyzer capital cost: \$920/m^2 electrode area
- Product separation: Distillation for ethanol (10% purity to 90%, \$90/ton), PSA for ethylene (\$25-\$50/ton)
- Financial: 20 yr. lifetime, 15% nominal interest, 25.7% tax
- Process: 100 ton/day production, CO_2 source cost of \$40/ton

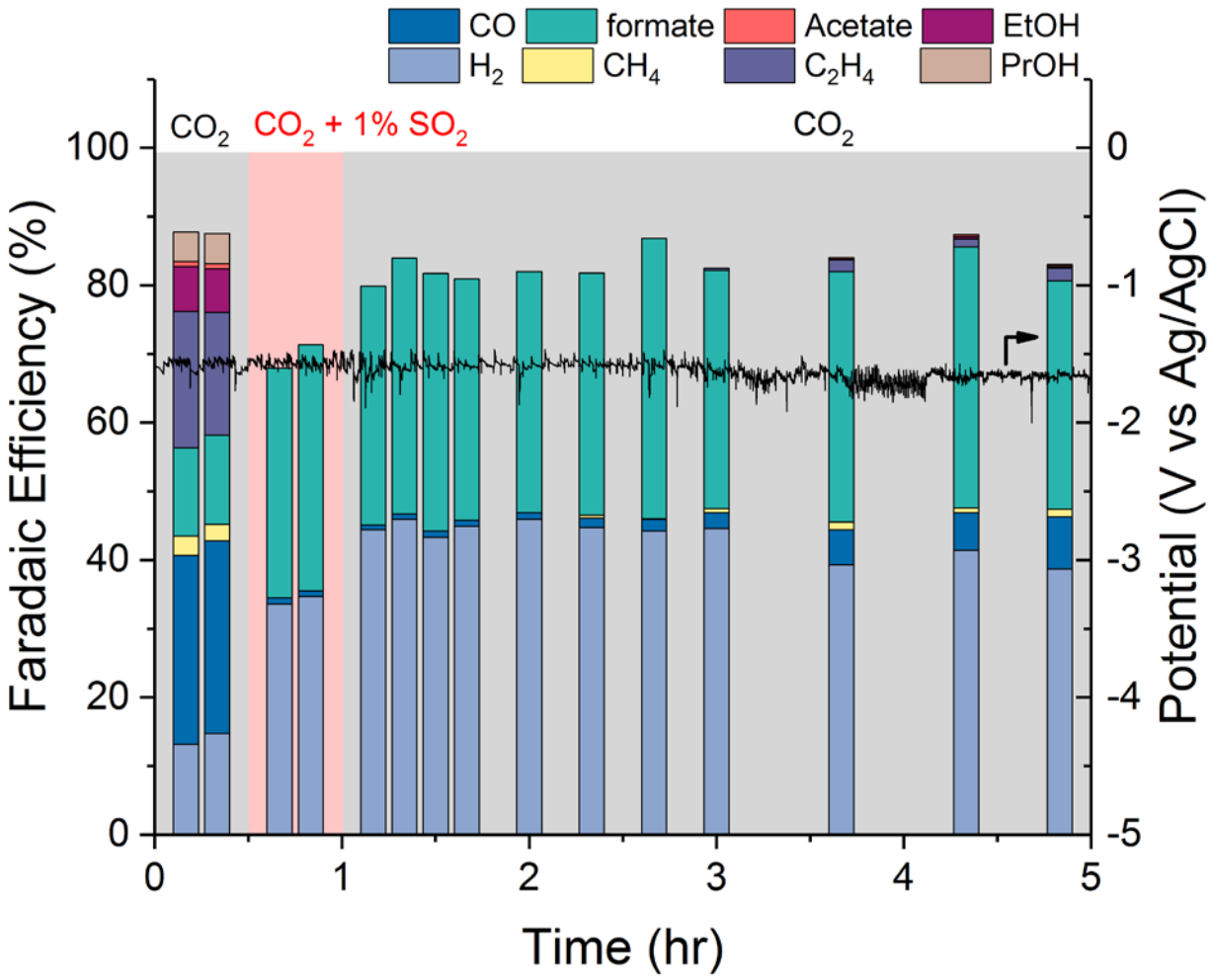
M. Jouny, W. Luc, F. Jiao, *Industrial & Engineering Chemistry Research* **57**, 2165-2177 (2018).

Influence of SO_2 on Ag and Sn catalyst



- Reduction in total CO_2 reduction FE due to preferential reduction of SO_2
- Performance recovered after SO_2 injection has been stopped

Influence of SO_2 on Cu catalyst

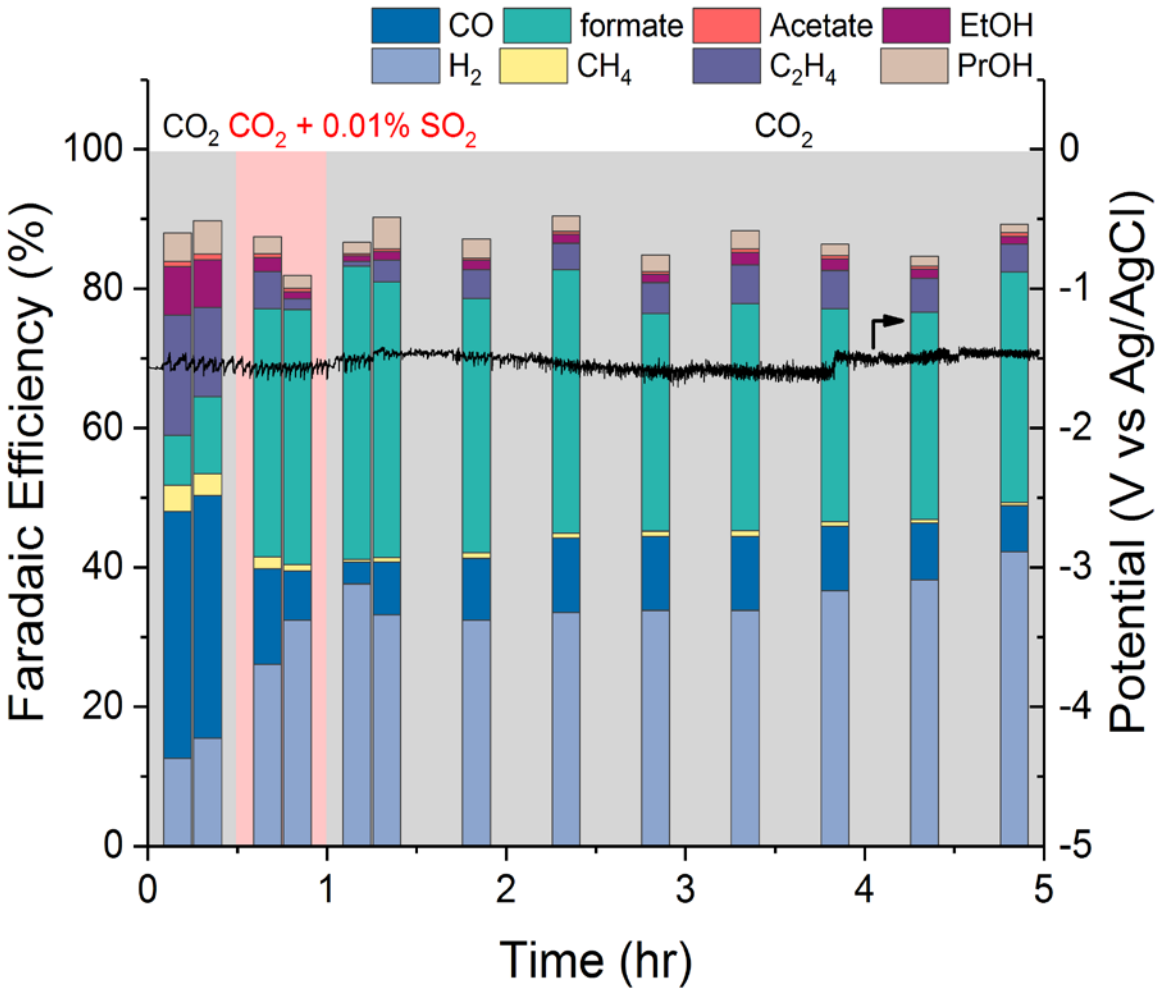


1% SO_2 in CO_2

A clear selectivity change towards formate

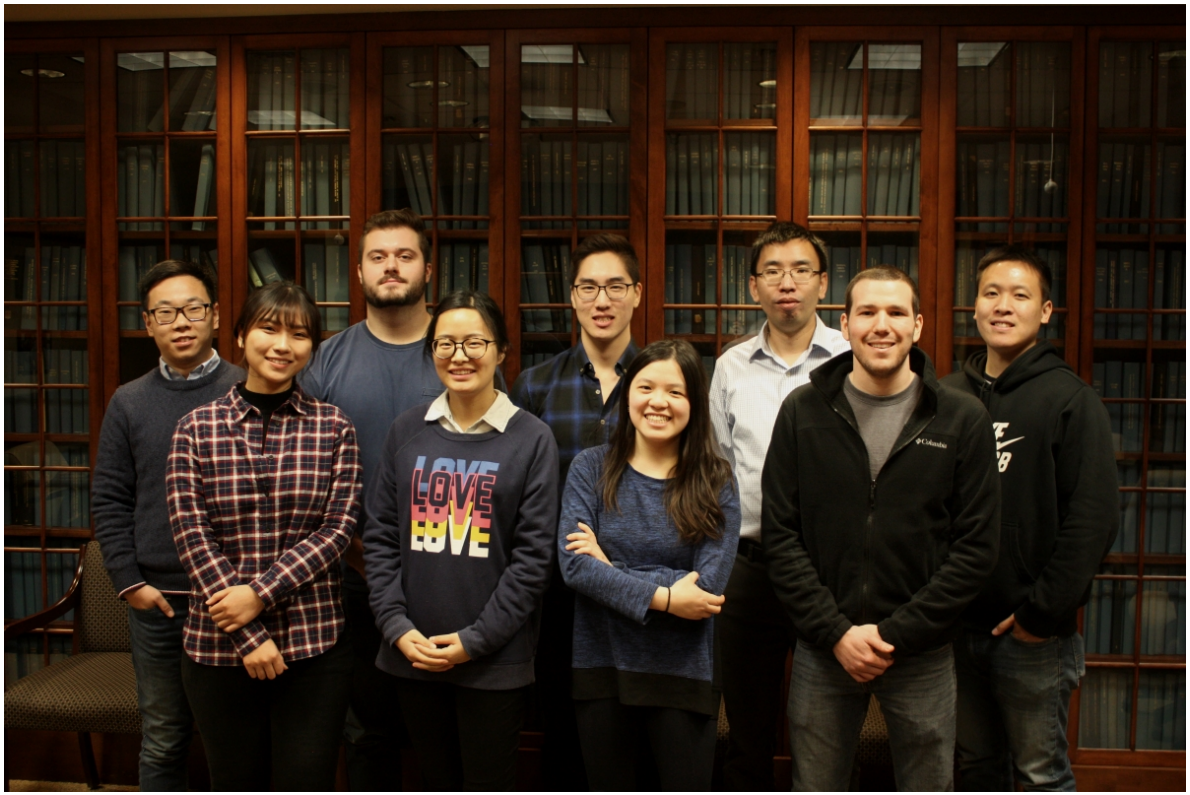
Slow recovery of C2+ selectivities

SO_2 concentration study on Cu



C2+ selectivity cannot be fully restored after 0.01% SO_2 exposure.

Acknowledgements



Project managers:
Andy O'Palko (Current)
Ted McMahon
Bruce Lani

Thank you