Electrocatalytic Reduction of CO_2 using Flow Cells with Gas Diffusion Electrodes

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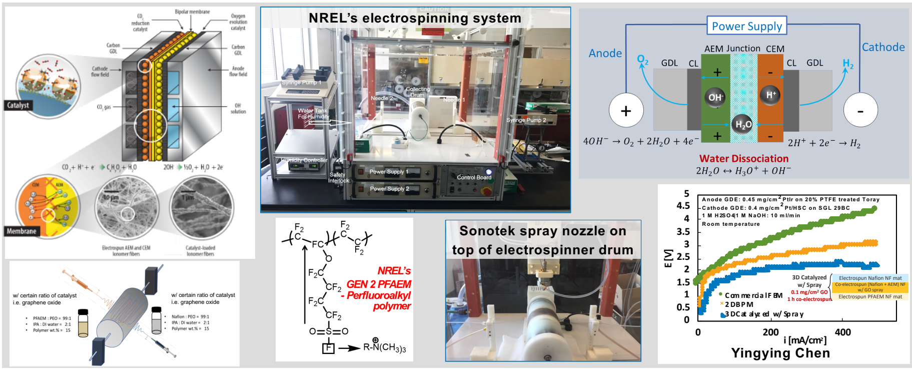
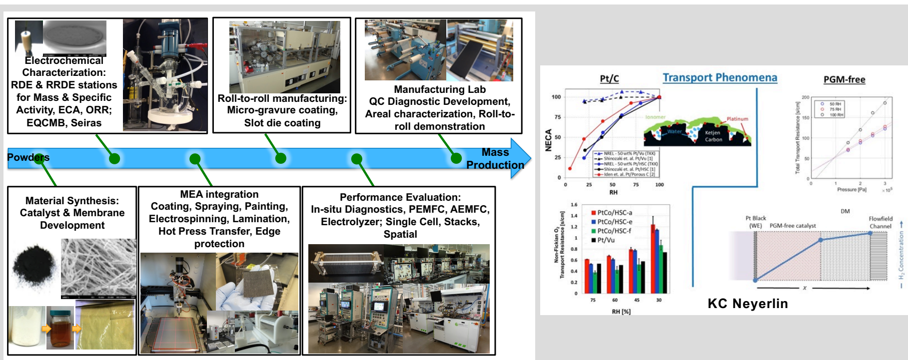


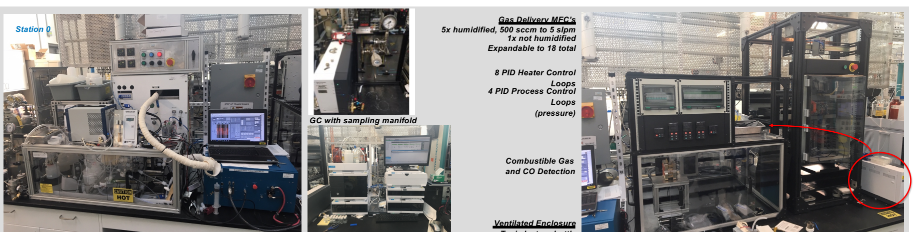
Bipolar membrane development

- Bipolar membranes (BPMs) prevent CO_2 (CO_3^{2-}) and product crossover in CO_2 electrolyzers.
- BPMs maintain pH gradient permitting water oxidation to occur in alkaline environment where earth-abundant electrocatalysts can be used.
- Dual fiber electrospinning of Nafion and PFAEM results in a 3D interface that has higher mechanical stability and lower area specific resistance (better performance) than a 2D BPM
- Adding catalysts, like graphene oxide, to BPM interface lowers water dissociation resistance
- Electrospinning is a versatile platform that enables fabrication of an array of membrane architectures



Component fabrication & device testing

- NREL's Energy Systems Integration Facility (ESIF) houses capabilities that span multiple scales and levels of integration – from materials synthesis to systems testing
- Over a decade of research in hydrogen fuel cells and water electrolysis systems has established an expertise and understanding needed to accelerate CO_2 electrolyzer development
- Techniques used to measure, model, and elucidate transport phenomena in gas diffusion electrodes in fuel cells can be applied to CO_2 electrocatalysis
- In-situ electrochemical diagnostics on devices that span mW - kW



Designed and built world-class CO2 test stands

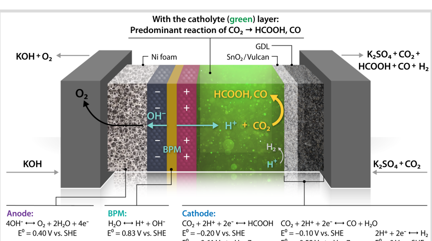
- *Anode and cathode can flow liquid (0-100 mL/min) or gas (0-4 SLPM)*
- *In-line automated gas sampling (two Agilent 490 MicroGCs)*
  - *H_2, CO, CH_4, C_2H_4, CO_2*
- *HPLC with autosampler for liquid product analysis*
- *PEEK-PTFE backpressure (0-60 psig) regulators optimized for dual-phase flow*
- *Ambient to 85° C operation*
- *Safety N_2 purge*
- *Flammable gas leak detection*
- *Enclosure ventilation exceeds NREL standard for chemical fume-hoods*

Designed for maximum modularity and ease of and maintenance/modifications

Ellis Klein, Guido Bender

CO_2 electrolysis test stands

- Testing CO_2 electrolyzers has more complex product analysis requirements than are needed for water electrolysis
- No commercially available test stands for CO_2 devices
- Experience gained from building and maintaining over a dozen fuel cell and water electrolysis test stands applied to design and assemble CO_2 electrolysis test stands
- Highly automated operation and on-line product analysis
- Standardized test bed to reproducibly evaluate and benchmark promising CO_2 reduction catalysts under conditions relevant to upscaling



Cell:
- Temperature: 60 °C
- Active area: 25 cm²

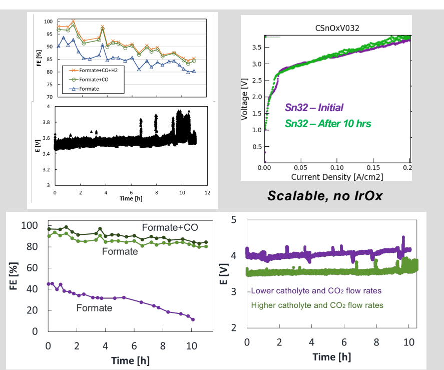
BPM:
- 2D BPM = Nafion+graphene oxide+AEM
- FumaSep FBM

Anode:
- Ni foam in 1 M KOH

Cathode:
- SnO_2 on C w/ Nafion in 0.5 M K_2SO_4

Faradaic Efficiency
- HPLC for liquid product identification and quantification
- GC for gas phase products

Yingying Chen, Ashlee Vise



Preliminary results: Formate

- Go/No-Go Milestone: "Demonstrate a CO_2 electrolyzer that has an area of 25 cm² and integrates a BPM with a catalyst-loaded MEA that can operate at over 150 mA/cm² for 10 hours with FE >80% non-hydrogen products"
- Targeted formate as the CO_2 reduction product for integration with biological upgrading to higher value products
- Hydrogen is the primary product without catholyte
- Starting to incorporate NiP_2 and Cu catalyst in cathode to achieve C-C products

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