Carbon Dioxide Reduction Reactors

Quinn Padovan, Caden Kuster

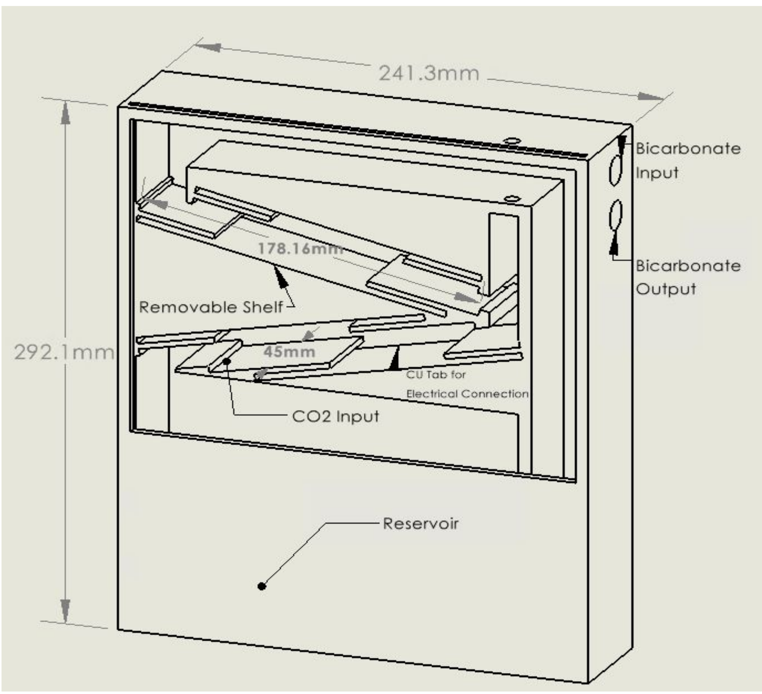
Solving problems related to energy conversion, storage, and efficiency

Carbon Dioxide Electroreduction Reactors

- Electroreduction reactors take research conducted in focused (3 electrode) cell designs and attempts to scale it up into a usable (2 electrode) flow cell that can produce large quantities of target products
- Enables the creation of target products such as ethanol and ethylene that can be used in a partially recycled fuel or in the production of chemicals or plastics
- The reactors use new research into the use of polymer membranes applied to electrocatalysts that improve selectivity and product yields in the reaction

Current Focus

- Two major parts of the reactor design are the structural design aspect and the chemical reaction facilitated by this design.
- Independent variables like bicarbonate flow rate, leakages of fluids, CO2 flow rate, and spacing of catalyst plating (reactor "shelves") must be optimized.
- Dependent factors of interest are product selectivity, durability, and CO2 conversion rate.



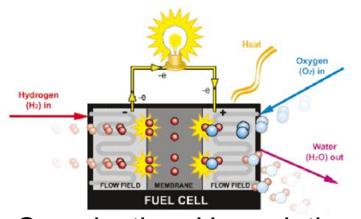
Version 3 reactor that incorporates removable shelves to be able to test large quantities of various electrodes

Future Directions

The second version of the reactor corrected many structural problems relating to issues like flow rates and leakage. Upcoming challenges that we will face are involved with investigating various catalysts and polymer combinations to try to produce optimal amounts of products. Additionally, issues with long-term reactor usage can start to be addressed, catalytic poisoning and even the capture of products are going to be upcoming challenges for our laboratory. Our current reactor designs will have to be significantly scaled to meet ideals on product production and ensure that reactions take place in a reasonable timeframe, influenced by the size of catalysts. Once products can be isolated, we will have to decide on how best to utilize these chemicals to create a partially sustained cycle The transformation of carbon dioxide into value-added products through the application of electricity is a promising method to aid the exploration and terraforming of Mars where CO2 makes up 95% of the atmosphere

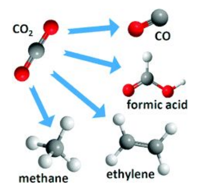
Electrocatalysis

- Reactions involving the transfer of both electrons and protons are ubiquitous in energy conversion processes.



O_2 reduction, H_2 evolution

Photosynthesis



CO_2 reduction

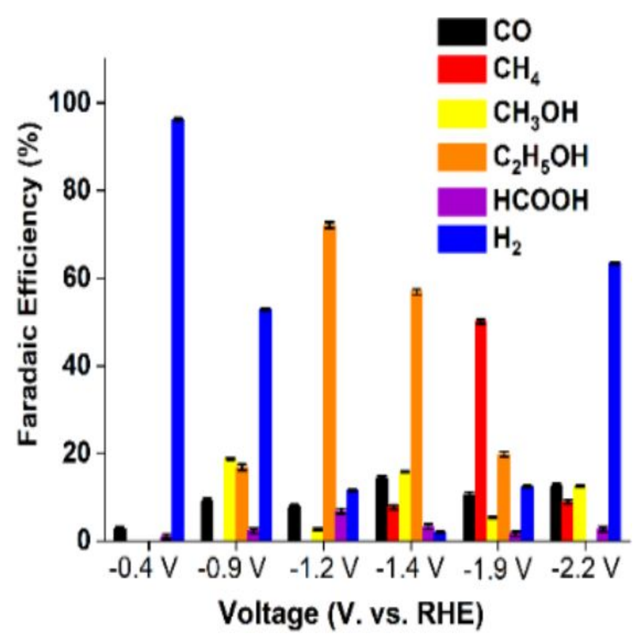
N_2 reduction

- We are developing novel electrochemical platforms to control proton and electron rates to catalysts using applied polymer membranes such as Nafion and Nafion-Teflon blends.
- By modulating proton transfer, we can improve the selectivity and yield of catalysts and understand reaction pathways.

Current Focus

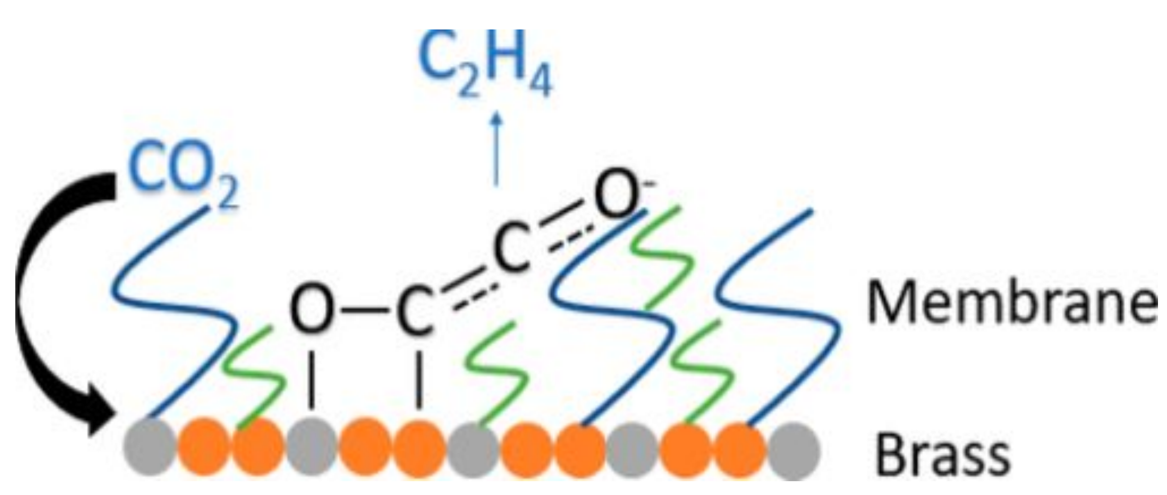
Reactor design has been made possible through work in the Barile group which has shown that metal electrodes modified with fluoropolymers increase the selectivity of CO_2 reduction. Recently, the Barile lab has discovered that a Nafion-modified copper (Cu) on silver (Ag) catalyst produces ethanol with up to 72% Faradaic efficiency, which is among the highest ever reported (Figure 2). This new application of Nafion blended polymers can improve metallic catalyst selectivity, which leads to increased selectivity of desired products such as ethanol. This research has informed structural design choices for the reactor and provided the pathway for the reaction inside the system to follow.

CO2 reduction product selectivities for the Nafion-modified Cu on Ag catalyst at different applied voltages. Ethanol yields are given by



Fluoropolymers/SAM's

Previous research in the Barile group is exciting in its application to electroreduction reactors. The application of copolymer blends of polyvinylidene fluoride (PVDF) and Nafion as well as a Teflon-Nafion blend that could be applied to catalysts have the potential to create high current density and yields. We have researched these polymer blends and have recently research the application of Self Assembled Monolayers (SAM's) to create C2 products of interest like ethanol, ethylene, and methanol which all have applied uses



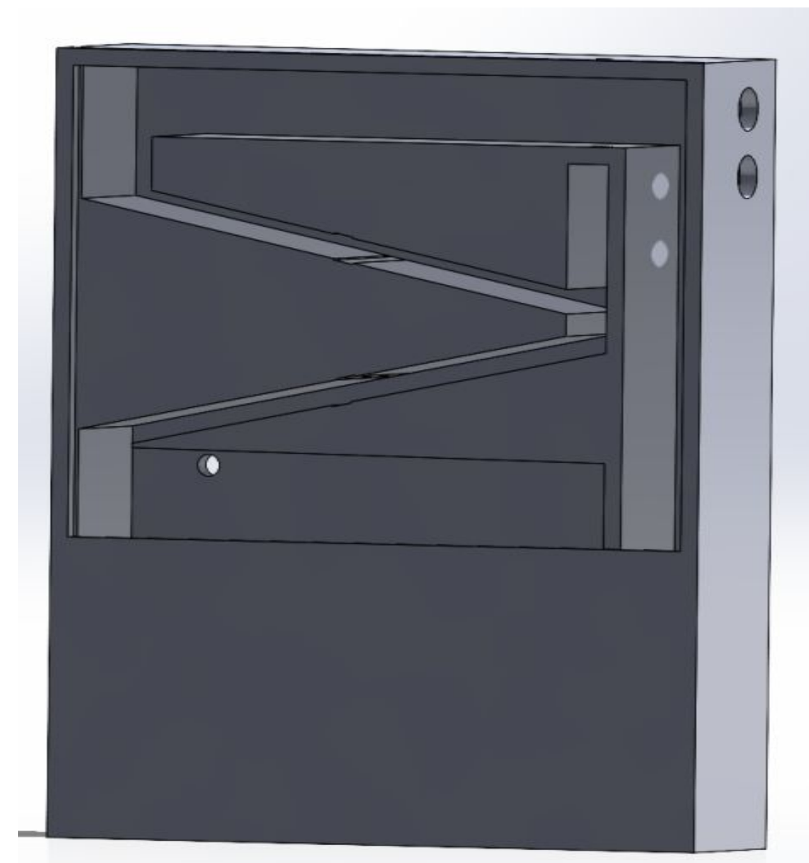
Scalable Reactors

- Our laboratory designs new electrochemical and structural approaches to optimizing reduction reactions and scaling highly specialized research
- Reactors will house pathways for the reaction and ensure that all factors are optimized to produce target products of ethylene and ethanol
- Large scale reactors are necessarily to produce usable quantities of target products in industrial settings

Current Designs

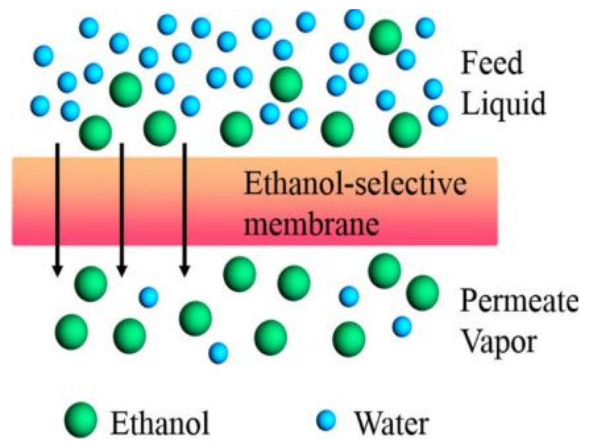
We have currently designed and tested three distinct versions of the reactors. The first started with three "shelves" that housed sheets of electrocatalysts that act as the working electrodes and facilitate the pathway for the reaction. Later, this was simply reduced to two shelves in order to fix flow rate issues and create a larger basin for the reactor reservoir. This larger reservoir was necessary to fix issues associated with the flow rate and leakage of the electrolyte solution. Fixing these leads to higher current density and yield.

Version 2 of the reactor that simplifies the overall design and was able to run tests of up to 15 hours



Future Directions

Pervaporation membranes provide a novel way to easily separate final solutions after the process of electroreduction. Target products like ethanol will have to separate from the sodium bicarbonate electrolyte solution. A Pervaporation membrane could remove this and leave us with isolated ethanol



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This material is based upon work supported in part by the NVSGC grant 80NSSC20M004