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# MEA Design Strategies: Driving Carbon-Neutral Economy through $CO_2$ Capture and Conversion


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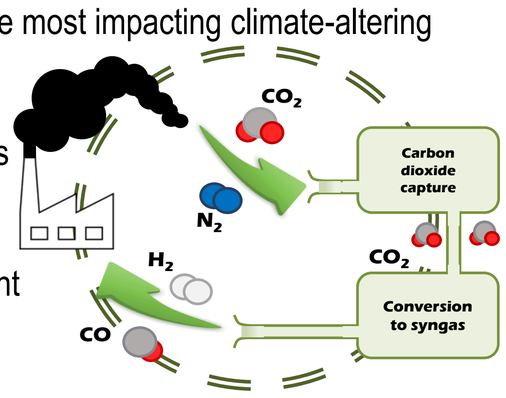
## Research context and motivation

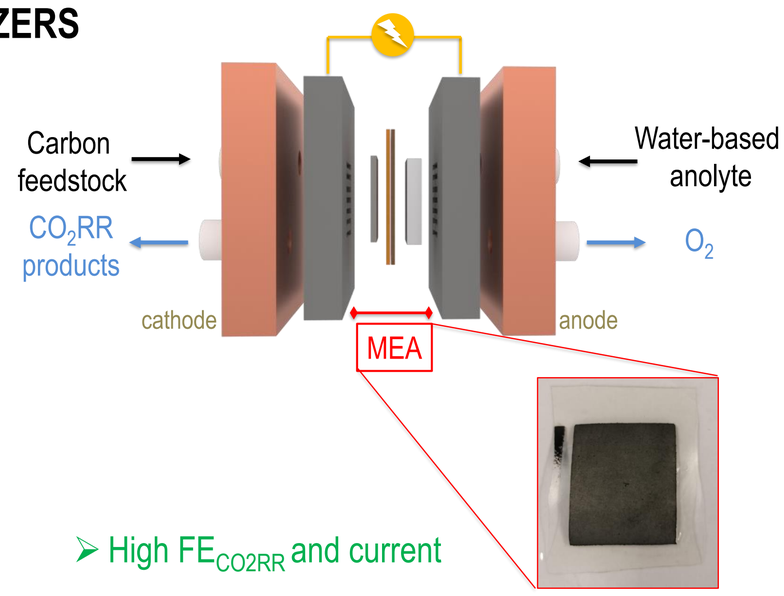
- The problem of global warming, undoubtedly caused by the human activities, becomes more and more pressing on our planet. Large amounts of greenhouse gases (GHGs) have been emitted in the atmosphere, contributing to the rise in temperatures. Among the GHGs, **carbon dioxide ($CO_2$)** is the one with the largest concentration in the environment and the longest residence time, thus representing the most impacting climate-altering substance.
- To reduce the $CO_2$ emissions in the atmosphere, **carbon capture and utilization (CCU)** technologies have been proposed as effective solutions. In this framework, **electrochemical processes** demonstrated to be intriguing strategies to implement $CO_2$ capture and valorization, possibly powered by renewable sources allowing a carbon neutral path.



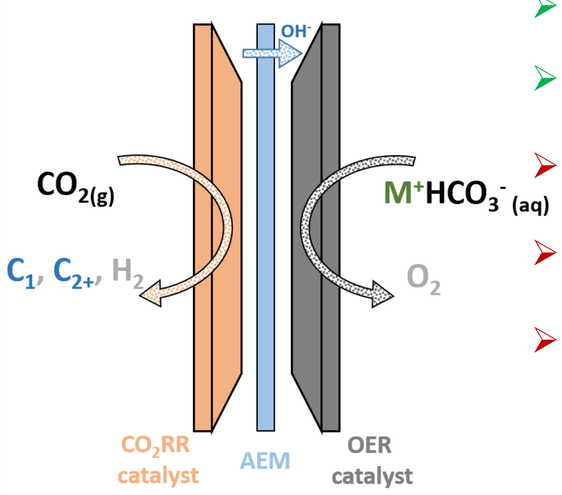

- The **Membrane Electrode Assembly (MEA)** is playing a central role in electrochemical devices able to convert $CO_2$ into e-fuels. The MEA is employed either in **gas-fed $CO_2$ electrolyzer**, or in liquid-fed $CO_2$ electrolyzers. The **bicarbonate electrolyzer** (liquid-fed) is a recent technology able to integrate the capture of $CO_2$ from a flue gas with the conversion.

## Addressed research questions/problems

- **MEA IN $CO_2$ ELECTROLYZERS**
  - ➢ Lower cell potential than microfluidic electrolyzer
  - ➢ Used in $H_2$-electrolyzer and fuel-cell
  - ➢ Easily up scalable




- **Gas-fed electrolyzer**

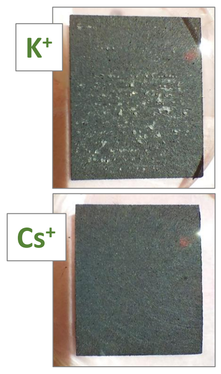



  - ➢ High $FE_{CO2RR}$ and current
  - ➢ Resistant to electrode flooding
  - ➢ Low single pass efficiency
  - ➢ AEM degradation
  - ➢ Salt deposition on cathode

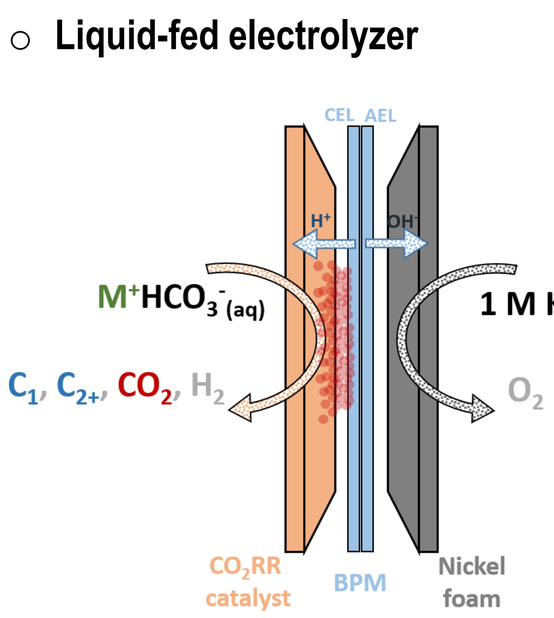
$CO_2 + H_2O + 2e^- \rightarrow CO + 2OH^-$

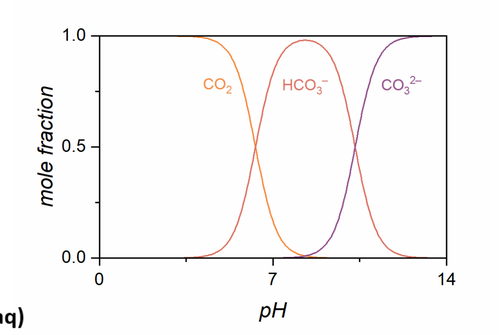
$CO_2 + OH^- \rightarrow CO + HCO_3^-$

$M^+HCO_3^-$ deposition



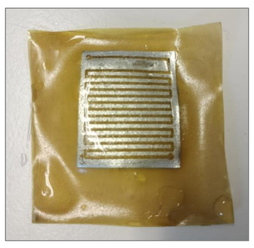

- **Liquid-fed electrolyzer**



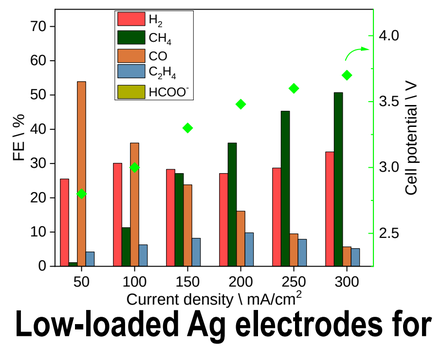

  - ➢ Integrated $CO_2$ capture and conversion
  - ➢ High single pass efficiency
  - ➢ No salt deposition
  - ➢ Lower $FE_{CO2RR}$
  - ➢ High cell potential

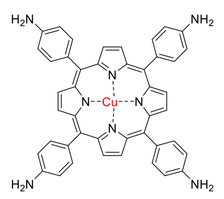
Silver sputtered MEA



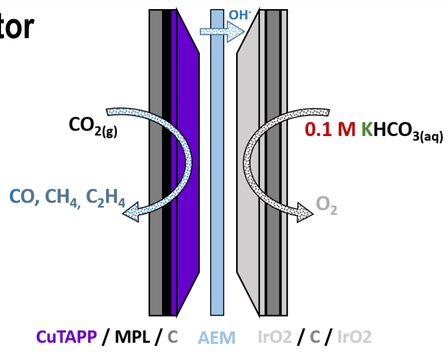
## Novel contributions

- **MEA engineering for $CH_4$ production in gas-fed reactor**

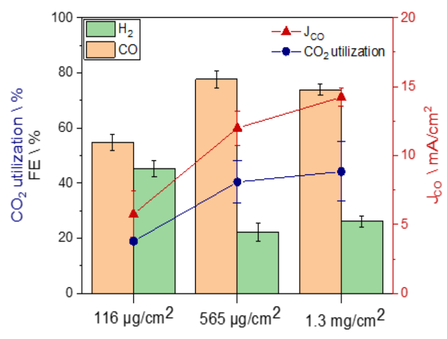


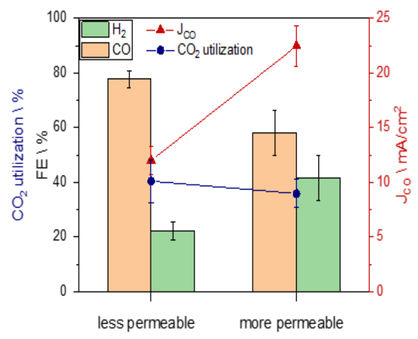



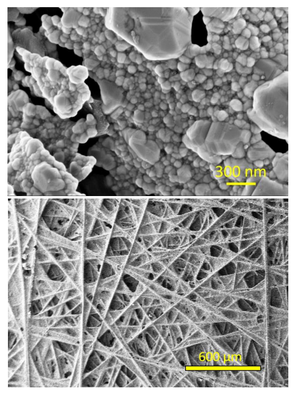

Catalyst synthesized by **Dr. Daniele Sassone**



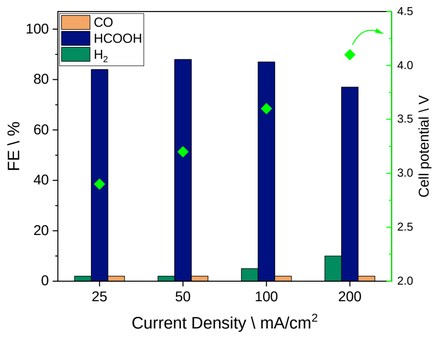

- **Low-loaded Ag electrodes for syngas production in bicarbonate reactor**

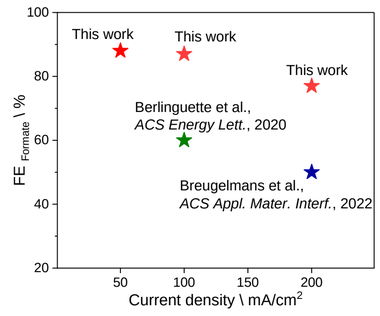


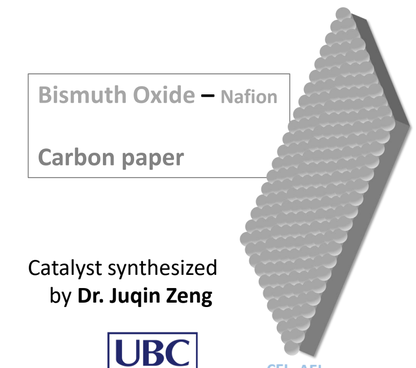




- **Selective formate production in bicarbonate reactor**

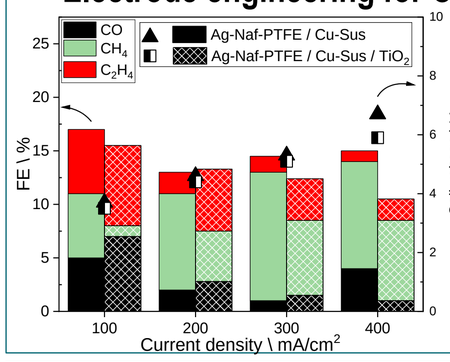


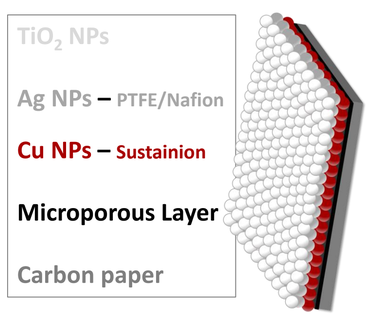



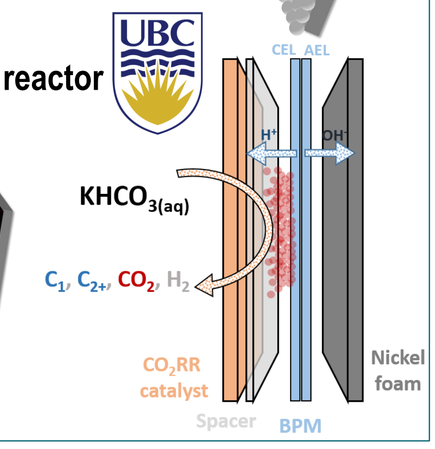




Catalyst synthesized by **Dr. Juqin Zeng**

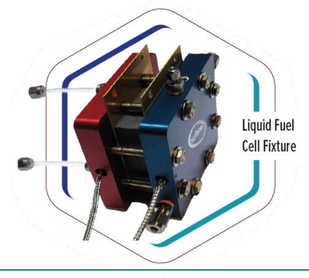
- **Electrode engineering for $C_{2+}$ products in bicarbonate reactor**




## Adopted methodologies




- Electrolytes: KOH, $KHCO_3$, $Na_2HCO_3$ and $CsHCO_3$
- µGC, HPLC and NMR for products detection
- PVD, electrodeposition and spray coating for catalyst deposition
- Characterization of catalyst material: FESEM, XRD
- Electrochemical Impedance Spectroscopy

## Future work

- Strategies to limit salt deposition at high currents in gas-fed electrolyzer
- MEA scale up to 25 $cm^2$ and 100 $cm^2$ in gas-fed electrolyzer
- Influence of additives (halogen ions) on $C_{2+}$ selectivity in bicarbonate electrolyzer
- Seawater-fed bicarbonate electrolyzer
- Strategies to decrease cell potential in bicarbonate electrolyzer
- MEA for low-energy electrochemical $CO_2$ capture

## Submitted and published works


- Mezza, A.; Pettigiani, A, and Sacco, A. (2021), "*An Electrochemical Platform for the Carbon Dioxide Capture and Conversion to Syngas*", Energies, vol. 14, no. 23, pp. 7869
- Agliuzza, M., Mezza, A., and Sacco, A. (2023), "*Solar-driven integrated carbon capture and utilization: Coupling $CO_2$ electroreduction toward CO with capture or photovoltaic systems*", Applied Energy, vol. 334, 120649
- Mezza, A., et al. (2023). "*Optimizing the Performance of Low-Loaded Electrodes for $CO_2$-to-CO Conversion Directly from Capture Medium: A Comprehensive Parameter Analysis*." Nanomaterials 13(16): 2314.
- Carpignano, A., et al. (2023). "*Italian Offshore Platform and Depleted Reservoir Conversion in the Energy Transition Perspective*." Journal of Marine Science and Engineering 11(8): 1544.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