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XXXVII Cycle

Electrochmical devices for carbon capture and valorization

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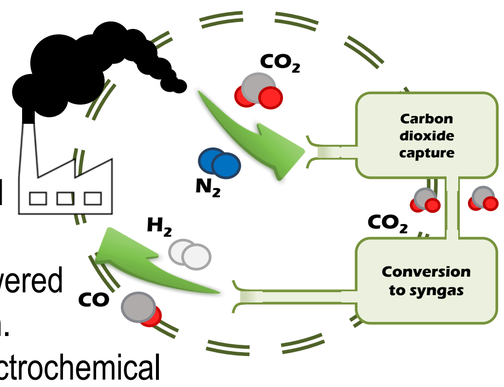
Research context and motivation

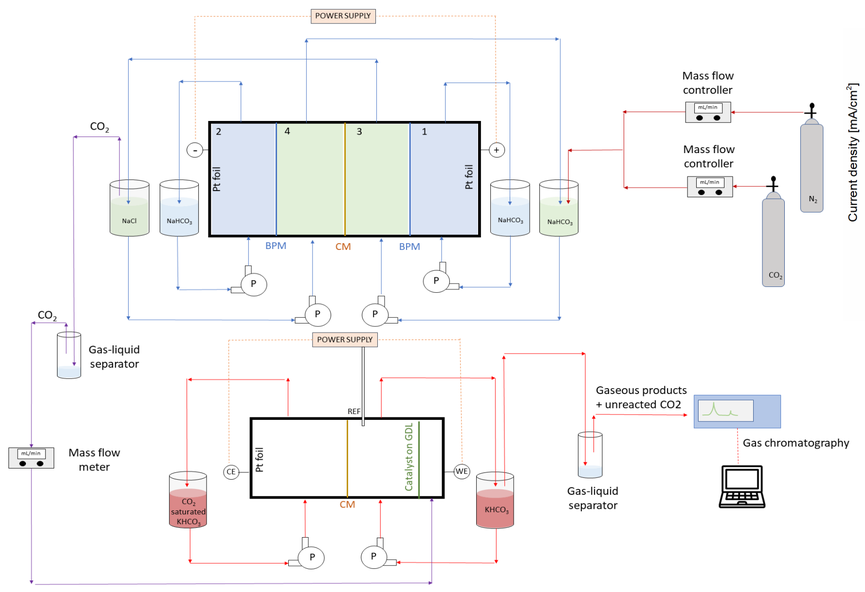
- The problem of global warming, undoubtedly caused by the human activities, becomes more and more pressing on our planet. Large amounts of greenhouse gases (GHGs) have been emitted in the atmosphere, contributing to the rise in temperatures. Among the GHGs, carbon dioxide (CO_2) is the one with the 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 platforms able to couple capture and valorization, possibly powered by renewable sources allowing a carbon neutral path.

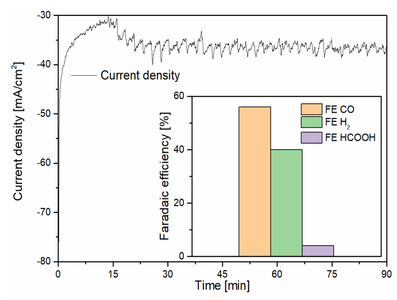


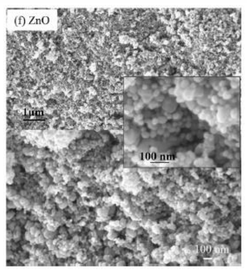
- Among the different products obtainable from the electrochemical CO_2 reduction reaction (CO_2RR), techno-economic analyses showed that carbon monoxide (CO) is the one with the highest profitability. Since in water-based electrolytes, HER is a competing reaction, syngas with tunable composition can be obtained.

Addressed research questions/problems

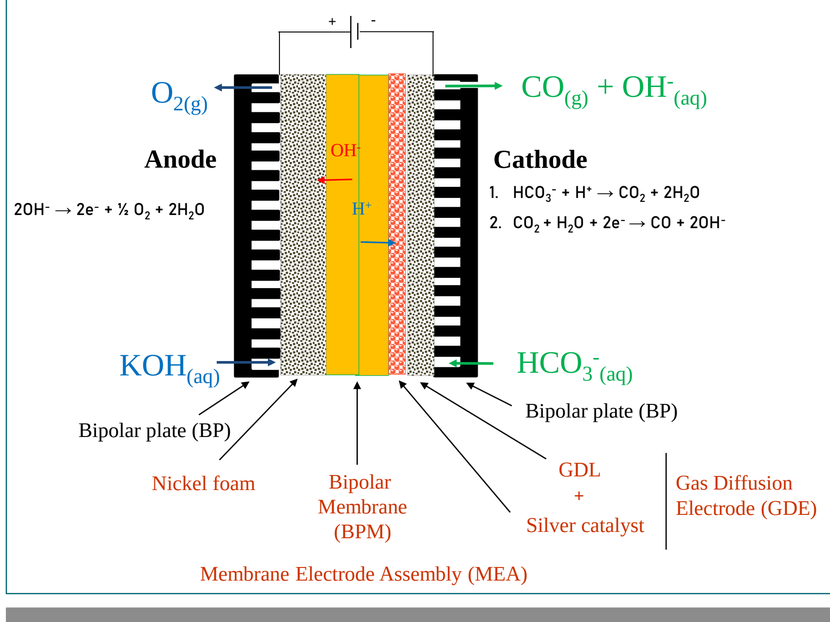
- **Coupled systems**
  The most simple idea is to couple a CO_2 capture module with a conversion module. Several techniques for capture and conversion devices have been deeply investigated in literature. We implemented a platform with an electrohcemical cell for electrodialytic extraction of CO_2 from bicarbonate as capture device, connected with a gas-fed flow cell used as CO_2RR device. The CO_2RR is activated by a nanostructured catalyst of ZnO.

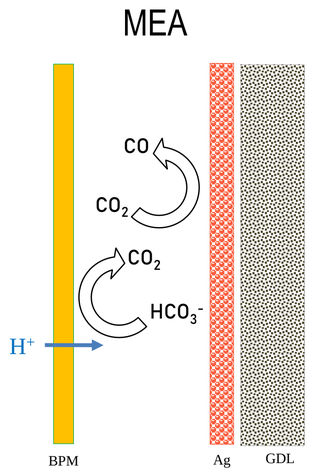






- **Integrated system**
  Stripping from capture media is very energy demanding. We focused on the possible integration of the capture and the conversion (ICCU), using the capture media directly as electrolyte for the CO_2RR in fuel cell-like device. The utilization of a MEA, including a bipolar membrane, is fundamental to have local release and conversion into CO of CO_2.

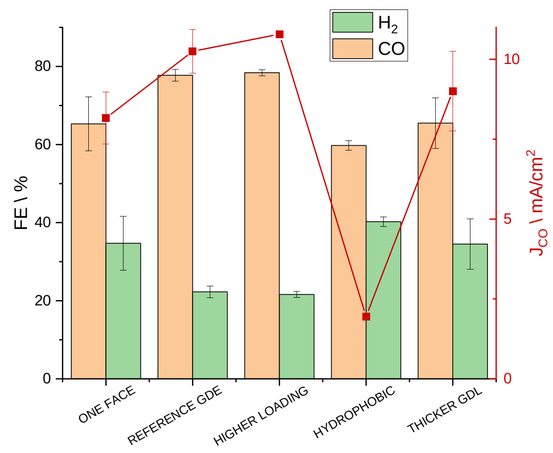


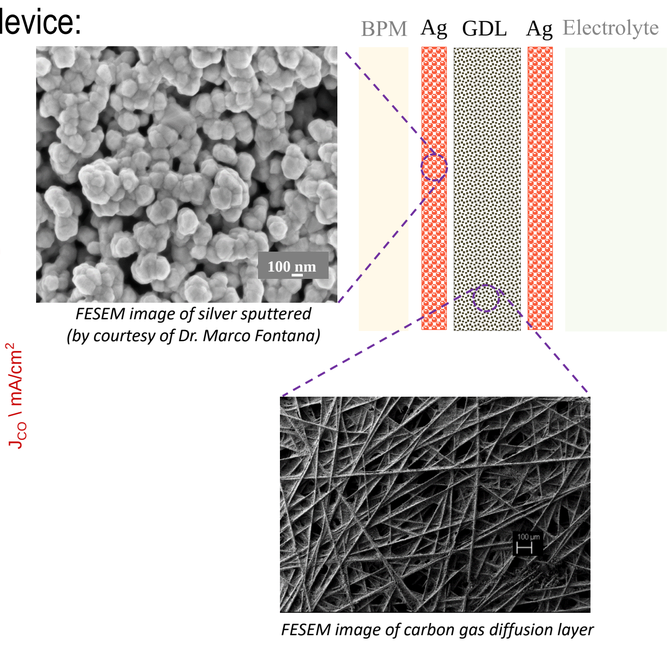


Novel contributions

- The work related to ICCU has been focused on the GDE and on its influence on the performance of zero-gap (fuel cell-like) device:

  1. GDL (thickness and hydrophilicity)
  2. Catalyst (thickness and position)



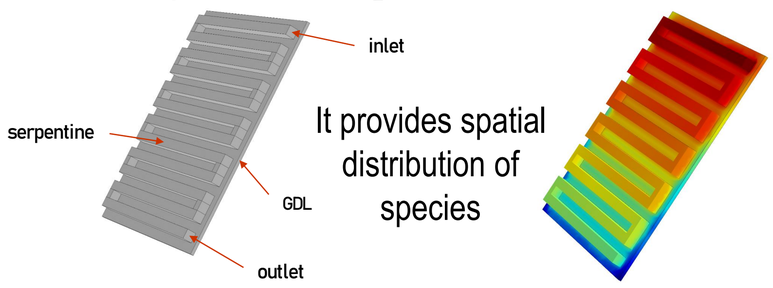


FESEM image of silver sputtered (by courtesy of Dr. Marco Fontana)

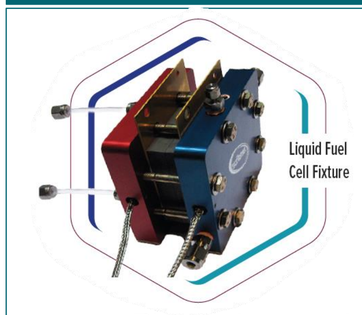
FESEM image of carbon gas diffusion layer

OPTIMAL GDE	• Hydrophylic GDL of 190 µm • Catalyst on both faces of GDL (loading: 565.4 µg/cm^2)

- Preliminary-model for CO_2RR in fuel cell-like device:



Adopted methodologies



- Fuel cell-like device
- MEA: nickel foam - Fumasep BPM - Sigracet carbon paper - - sputtered silver
- Electrolytes: KOH and $KHCO_3$
- Potentiostat for electrochemical characterizations
- µGC for gasseous products analysis in time
- Physical vapor deposition of silver
- Characterization of catalyst material
  - FESEM
  - XRD
- COMSOL for MEA modeling

Future work

- Increase currents and FE_{CO} improving the morphology of catalyst and GDE
- Implement a stable and efficient plant for Integrated Carbon Capture and Utilization
- Introduce cheaper catalyst material for CO_2RR in zero-gap electrolyzer
- Get a reliable model for MEA in CO_2RR and ICCU systems
- Exploit the zero-gap electrolyzer for low energy CO_2 capture from flue gas

List of attended classes

- 02UMPRS - An Introduction to Climate Change (28/3/22, 4)
- 01DMMKG - Impedance spectroscopy for electrochemical processes (10/2/22, 4)
- 01DMZIY - Photo-Electro-Catalytic Technologies for a Sustainable Chemical I. (17/6/22, 6)
- 01DUBRU - Understanding electrochemical processes using EIS (21/9/22, 4)
- Introduction to COMSOL MULTIPHYSICS (9/5/22, 12h)
- Short Courses on Electrochemistry (28/6/22, 12h)
- 02LWHRV - Communication (14/4/22, 1)
- 01SHMRV - Entrepreneurial Finance (12/1/22, 1)
- 08IXTRV - Project management (11/1/22, 1)
- 01RISRV - Public speaking (14/1/22, 1)
- 01SYBRV - Research integrity (13/1/22, 1)

Submitted and published works

- Mezza, A.; Pettigiani, A, and Sacco, A., "*An Electrochemical Platform for the Carbon Dioxide Capture and Conversion to Syngas*", Energies, vol. 14, no. 23, 2021, pp. 7869

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