Strategies for improving GDE performance by a uniform dispersion of catalyst nanoparticles and an optimal Nafion content

CREST
Catalytic Reaction Engineering for Sustainable Technologies

Politecnico di Torino

Strategies for improving GDE performance by a uniform dispersion of catalyst nanoparticles and an optimal Nafion content

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2021 VIRTUAL MRS SPRING MEETING & EXHIBIT
April 18–23, 2021

OVERVIEW

The electrochemical CO_2 reduction represents a promising alternative to mitigate **CO_2 emissions** and combat **climate change**[1].

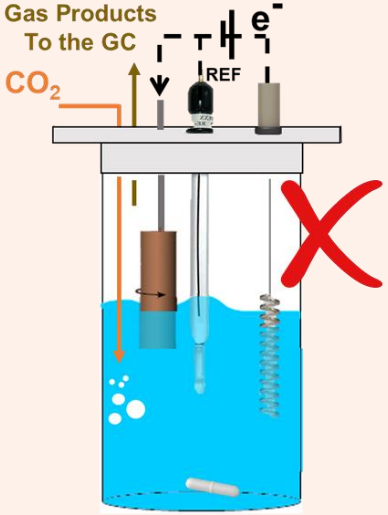
In this work, the catalytic ink deposition on a carbon paper support has been carried out both by **airbrushing** (manual) and by **spray-coating** (automated).

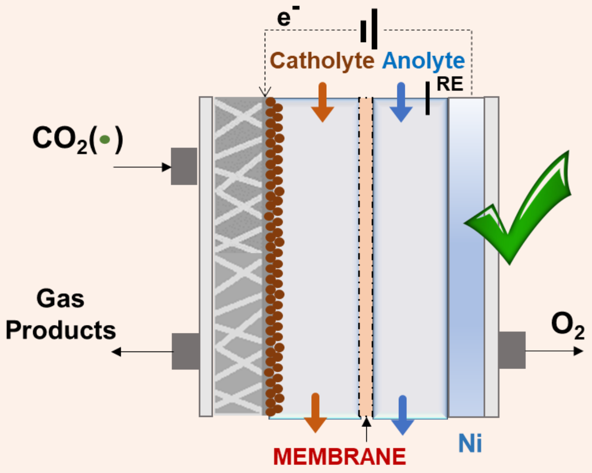
Cu-based catalysts[2] have been used to perform the EC-CO_2RR in a GDE-based setup.

The physical-chemical properties of the catalytic materials employed have been investigated through different characterization techniques.

AIMS

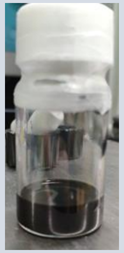
- To overcome the **limitations** shown by configurations with **CO_2 dissolved** in the electrolyte.
- To **exploit** the potential of **Copper-based** catalysts in **prompting the C-C coupling** and **enhancing alcohols production.**
- To achieve a **more uniform deposition**[3] of the catalyst particles by means of an **automated and scalable technique.**

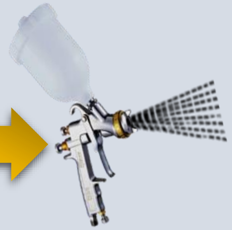




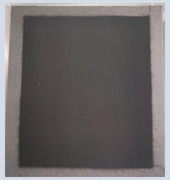
MATERIALS AND METHODS

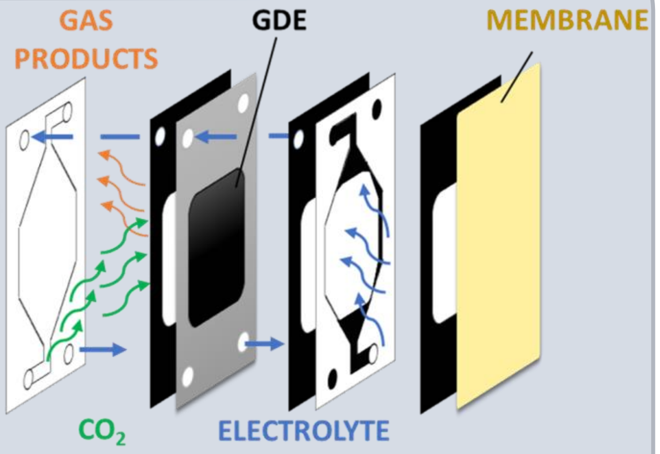
Cu-based catalysts have been prepared by **co-precipitation method**.





GDE active area:
10 cm²





- The catalytic ink consists of: **Cu-based catalyst** nanoparticles, carbon support (**Vulcan XC 72R**), **Nafion dispersion** and **isopropyl alcohol**.
- The catalytic ink has been deposited onto a porous and conductive support by **airbrusher**/**spray coater**.
- Electrochemical measurements in a **continuous flow cell** at ambient conditions.

3-electrode systems:
- Working Electrode: Cu-based GDE
- Reference Electrode: Ag/AgCl
- Counter Electrode: Ir-MMO plate

OUTCOME OF THE WORK

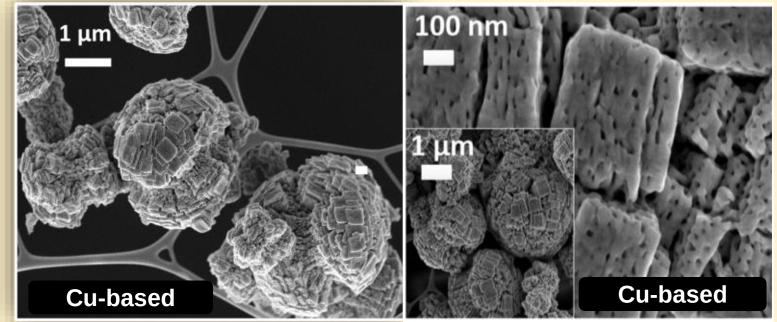


Fig. 1 FESEM micrographs of the synthesized materials.

Microspherical particles made up of rectangular section-structures can be observed.

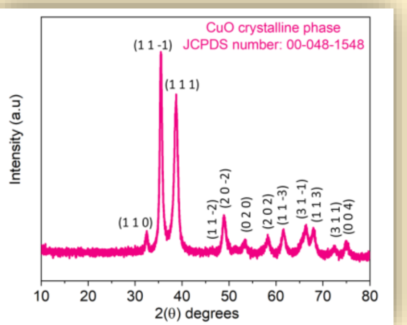


Fig. 2 XRD pattern of the synthesized materials.

The XRD analysis has detected the presence of only CuO in the **crystalline structure**.

Table 1. Physical-chemical properties of the synthesized material.

Catalyst	BET surface area, $m^2\ g^{-1}$	Total pore volume, $cm^3\ g^{-1}$	Crystallite size, nm (11-1) facet of CuO
Cu-based	**23.65**	0.131	**14**

The **Cu-based** catalyst is constituted by **nanocrystals**.

OUTCOME OF THE WORK

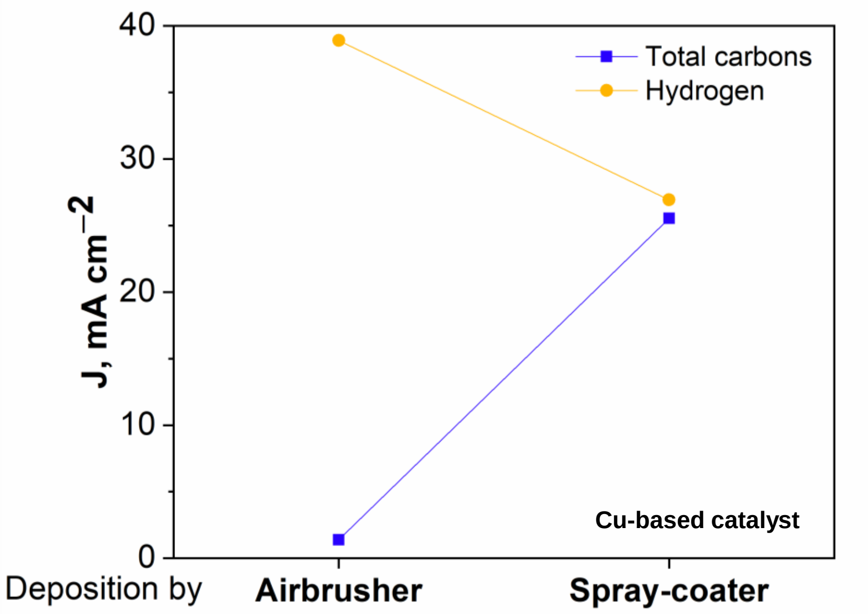


Fig. 3 Effect of the deposition technique on partial current densities (applied current density: 50 mA cm^{-2}).

The ***spray-coated*** electrode far exceeded the performance of the hand-made electrode.

A higher activity (>~**10 mA cm^{-2}**) has been evidenced by the **spray coated-electrode** during linear sweep voltammetry under CO_2 flow.

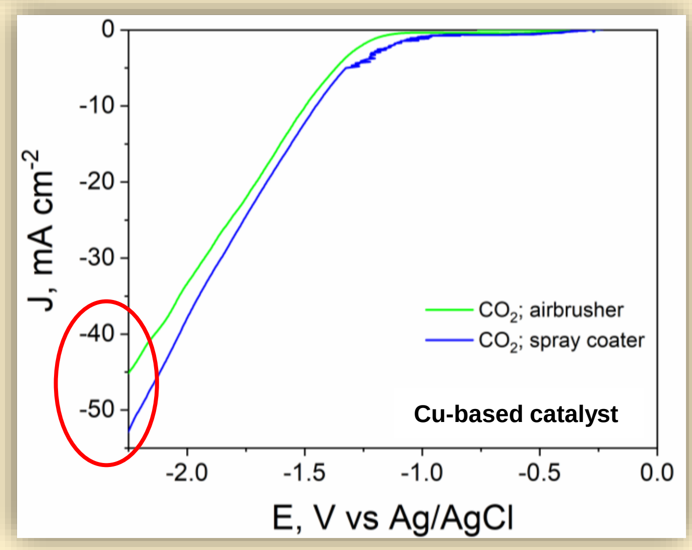


Fig. 4 Linear sweep voltammetry

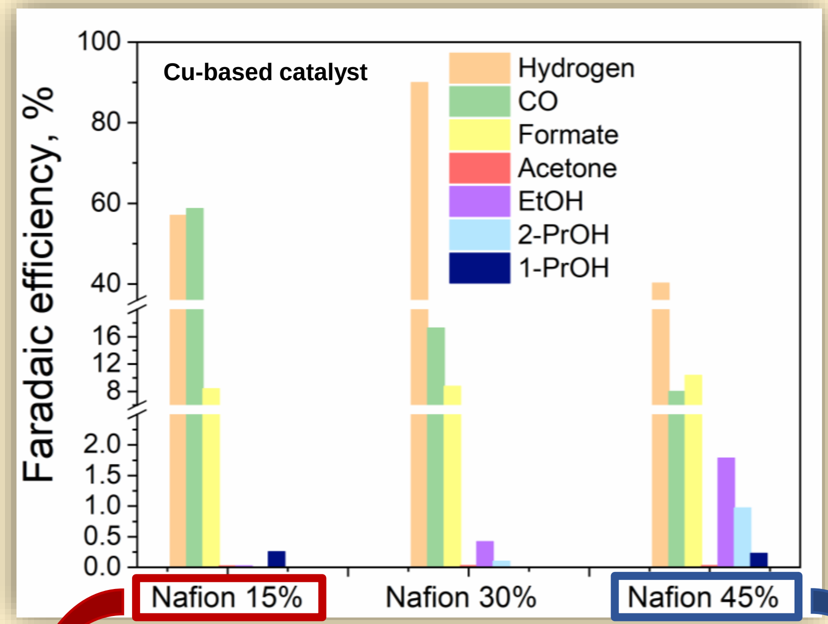


Fig. 5 Faradaic efficiencies of liquid and gas products: Nafion content effect.

A **lower** Nafion content has led to increase CO selectivity; whereas, a **higher** Nafion content has promoted C_{1+} production.[4]

RESEARCH HIGHLIGHTS

- The Cu-based catalysts here synthesised by co-precipitation method promoted C_{2+} products formation and hampered the hydrogen evolution reaction.
- A more uniform and controlled catalyst layer deposition enhanced the electrocatalytic activity.
- The spray-coated electrode outperformed the hand-made one, with FE of ~30% towards added-value products.
- The Nafion content has a relevant effect in the selectivity of the process.

Horizon2020
European Union Funding
for Research & Innovation

REFERENCES AND ACKNOWLEDGEMENT

SunCO2Chem

SATURNO

1 Guzmán, H.; Salomone, F.; Batuecas, E.; Tommasi, T.; Russo, N.; Bensaid, S.; Hernández, S. How to make sustainable CO_2 conversion to Methanol: Thermocatalytic versus electrocatalytic technology. Chem. Eng. J. **2020**, 127973. DOI:10.1016/j.cej.2020.127973

2 Guzmán, H.; Russo, N.; Hernández, S. CO_2 valorisation towards alcohols by Cu-based electrocatalysts: Challenges and perspectives. Green Chem. **2021**, 23(5), 1896–1920. DOI:10.1039/d0gc03334k

3 Jhong, H.R.Q.; Brushett, F.R.; Kenis, P.J.A. The effects of catalyst layer deposition methodology on electrode performance. Adv. Energy Mater. **2013**, 3(5), 589–599. DOI:10.1002/aenm.201200759

4 Guzmán, H., Zammillo, F., Roldán, D., Galletti, C., Russo, N., & Hernández, S. Investigation of Gas Diffusion Electrode Systems for the Electrochemical CO_2 Conversion. Catalysts **2021**, 11(4), 482. DOI:10.3390/catal11040482

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Action programme under the SunCoChem project (Grant Agreement No 862192) and from the Piedmont Region under the Saturno project (https://saturnobioeconomia.it/).