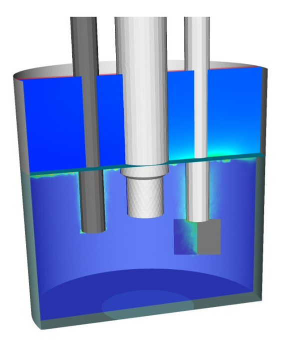
CINTECX CHALLENGE 2024



Optimization and scaling-up of electrochemical water splitting for H_2 generation

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Introduction

Selection of OER* catalyst**

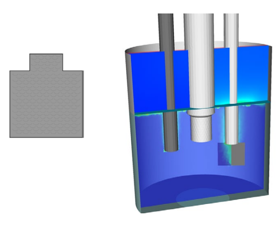
- Potato peels hydrochar (PP-HC) [1,2]
- Laser oxidation [3]

Water splitting costs
Environmental impact
Catalyst functional groups

*OER: Oxygen evolution reaction
**Results obtained out of project Challenge 2023

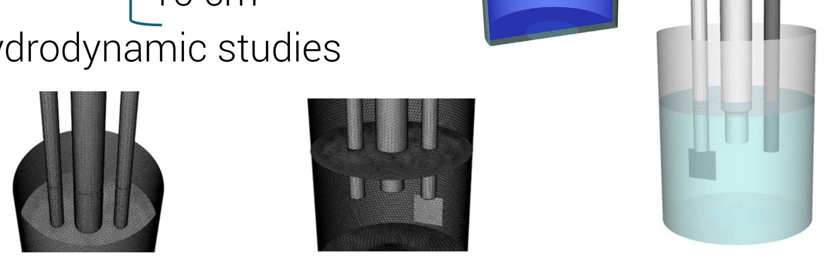
Scale-up validation

- Catalytic working electrode — 1 cm^2 / 10 cm^2
- Electrochemical and hydrodynamic studies



Scale-up simulations

Ansys FLUENT



The reactor geometry was modelled in order to fit its thermodynamic response during water splitting processes.

Materials and methods

Optimal electrode-laser modification

Industrial Deep UV-Excimer laser LEAP-60A

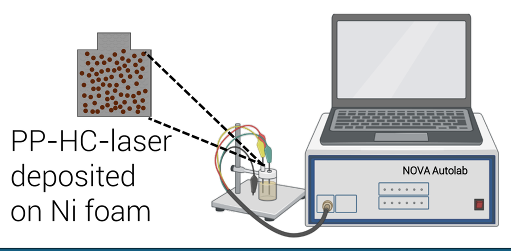
Application of 371.3 mJ/cm^2 in 10 repetitions to PP-HC electrode, obtaining **PP-HC-laser**.

Surface analysis

PLu Neox, Sensofar, USA

To measure and quantify surface roughness, several parameters are commonly utilized, including Rz (Maximum height of the profile), Rq (Root mean square roughness), Rh (Peak height) and Ra (Arithmetic mean roughness).

Electrocatalytic activity

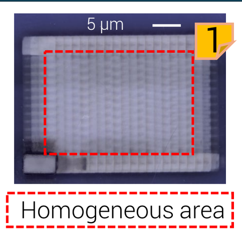


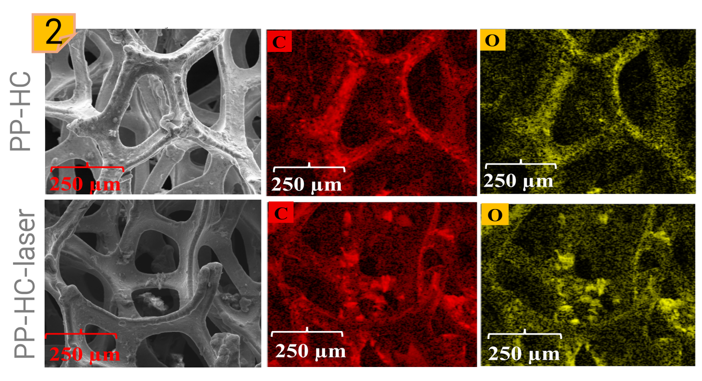
Reference electrode	Ag/AgCl
Counter electrode	Graphite stick
Working electrode	Catalytic electrode (Ni foam+0.25 mg/cm^2 catalyst)
Solution	NaOH 0.1 M
Potential window	0 – 0.74 V
Scan rate	0.01 V/s

Results

Evaluation of the laser homogeneity

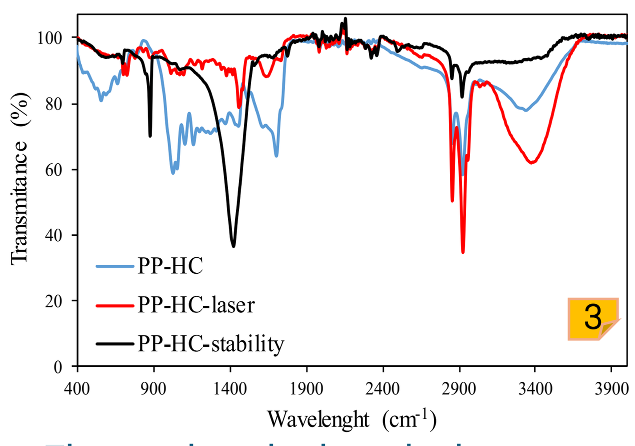
The unreported preparation of the PP-HC-laser electrode resulted suitable, considering the reproducibility of the physicochemical properties and the intensity homogeneity of the applied laser (Fig.1).





Functional groups analysis

PP-HC is homogeneously distributed on the Ni foam electrode (Fig. 2). Slight differences were found between PP-HC and PP-HC-laser, apart from the higher oxygen content which demonstrates the oxidation capacity of the laser beam.



Moreover, FTIR spectra (Fig.3) verified more clearly the laser treatment enhanced oxygenated functional groups presence, reducing the alkenes content.

Moreover, the oxygenation of the surface (Fig. 4) after laser application is tangible, reducing C-C and C-O-H groups (Fig. 5).

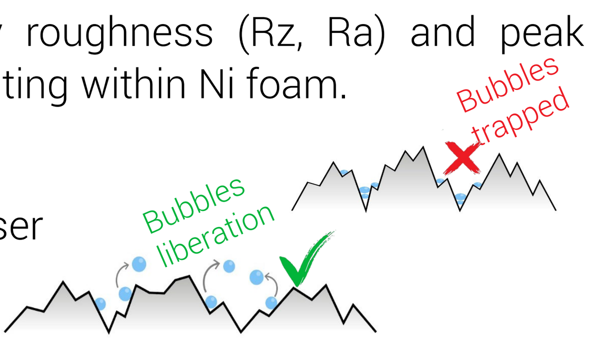
Surface analysis

The catalytic electrode has higher roughness (Rz, Rq, Ra) than Ni foam, which has a smoother surface (Rh).

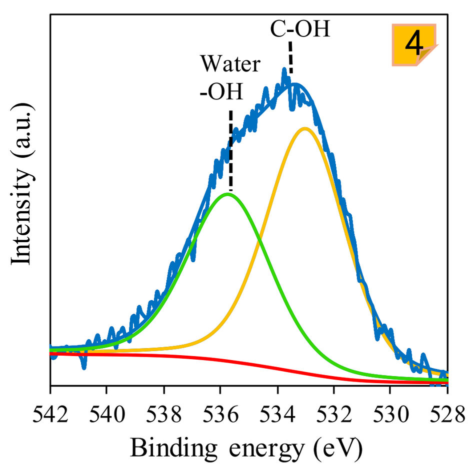
Laser treatment reduces slightly roughness (Rz, Ra) and peak height (Rh) due to the catalyst melting within Ni foam.

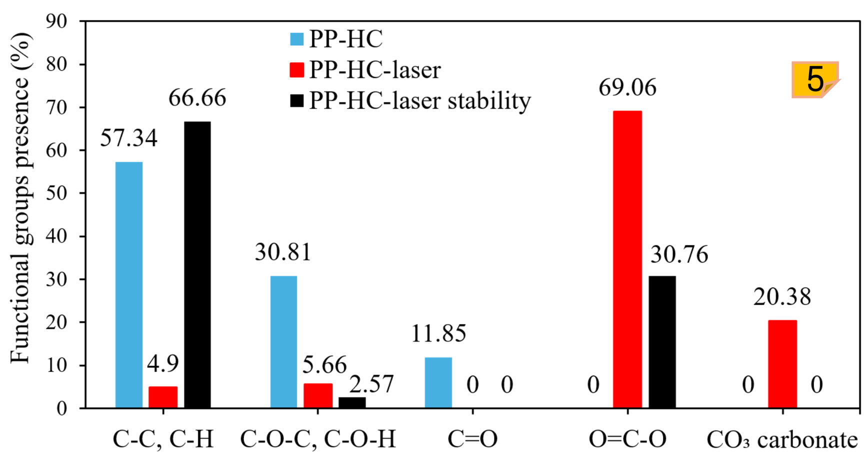
Anticipates/explains:

- High stability of PP-HC-laser
- Better H_2 or O_2 liberation



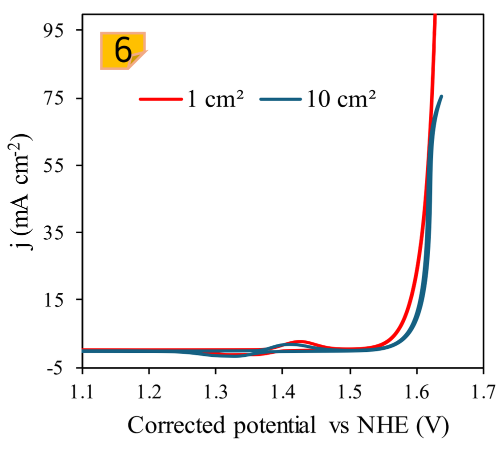
Electrode	Rz (mm)	Rq (µm)	Ra (µm)	Rh (mm)
Ni foam	1.8	225	176	0.68
PP-HC	3.4	210	154	1.7
PP-HC-laser	3.2	245	127	1.5





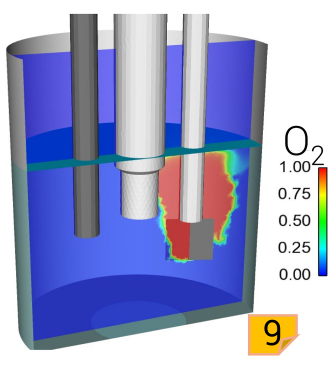
Electrochemical analysis

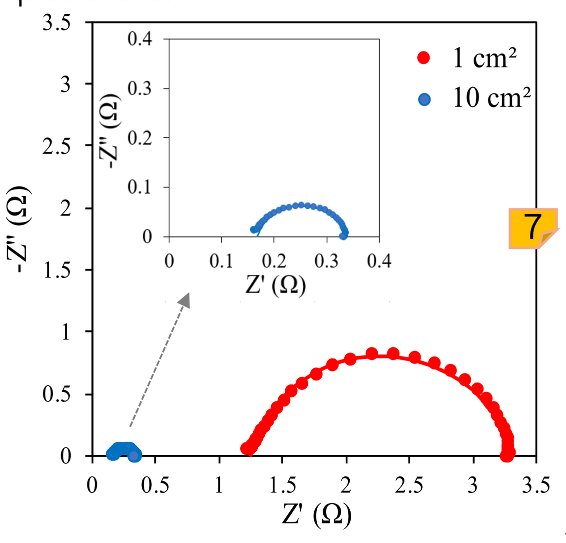
Increasing the catalytic working electrode area 10 times resulted in a practically constant electrochemical response (Fig. 6).



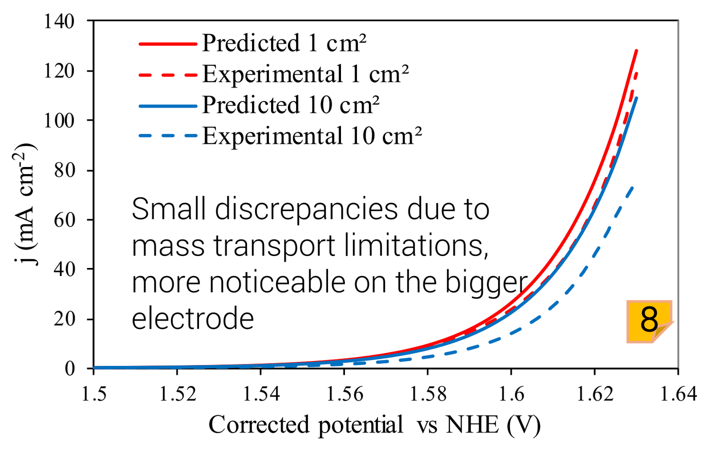
Electrochemical impedance spectroscopy

The electrochemical impedance spectroscopy (EIS), showed better results for the bigger electrode (Fig. 7), showing the scale-up of the process would be possible.



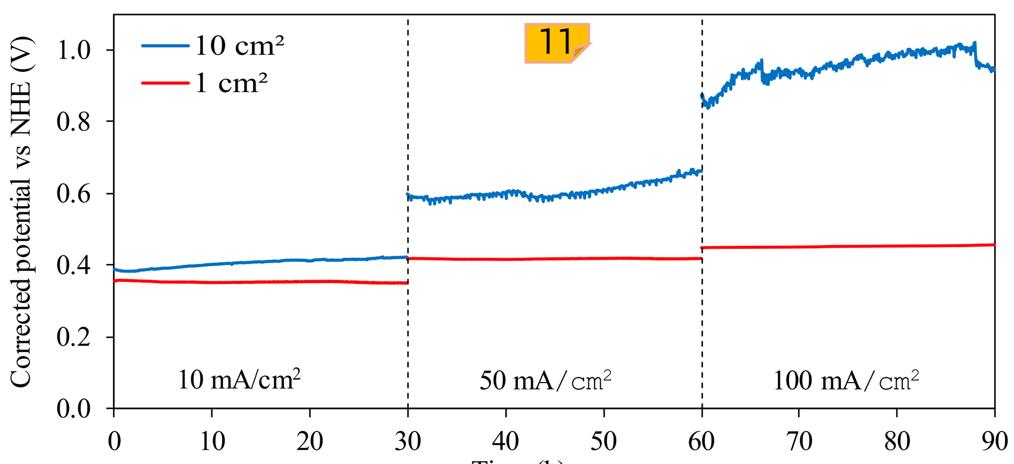


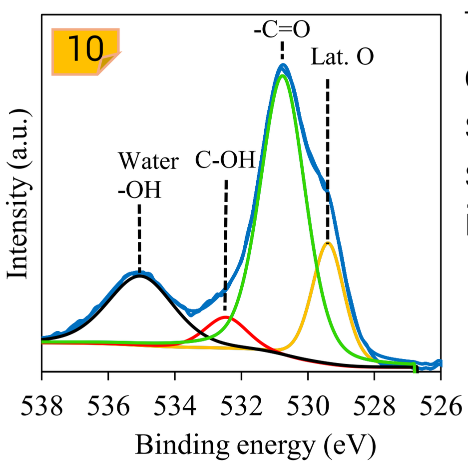
Scale-up simulations



Experimental and CDF predicted results were compared (Fig. 8), showing the power of CFD model to predict the electrocatalytic performance. Moreover, the gas released was simulated (Fig. 9).

Chronoamperometry studies





The long-term usage of the electrodes caused surface oxidation (Fig. 10). More stability is required at higher electrode sizes (Fig. 11), thus, as main conclusions, it is needed to:

- Explore new electrode preparation options
- Apply modifications to enhance stability
- Consider new cell geometries

References

[1] A. M. Díez, M. Bolaños-Vázquez, S. Chiussi, M. Pazos, M. A. Sanroman. Screening of agroindustry residues for their usage as oxygen evolution reaction catalysts. J. Environ. Chem. Eng. 12 (2024) 114527.

[2] A.M. Díez, S. Escudero-Curiel, S. Chiussi, M. Pazos, M. Á. Sanroman "From agroindustrial residues to catalysts for green hydrogen production" *10th carbocat International Symposium on Carbon for Catalysis*, Firenze, Italy, June 2024

[3] Aida M. Díez, Stefano Chiussi, Marta Pazos, M. Ángeles Sanromán, "Laser oxidation of a carbon-based catalyst for upgrading overall water splitting performance", *44th annual meeting of the RSEQ Specialized Group in Electrochemistry +5th E3 Mediterranean Symposium*, Basque country, Spain, July 2024

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