FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

araid
FUNDACIÓN AGENCIA ARAGONESA PARA LA INVESTIGACIÓN Y EL DESARROLLO

4AirCRAFT

Air Carbon Recycling for Aviation Fuel Technology

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FAPESP 60 SCIENCE, CULTURE AND DEVELOPMENT 1962 - 2022

FACTS & FIGURES – Aviation sector

4.5 billion
passengers were carried by the world's airlines

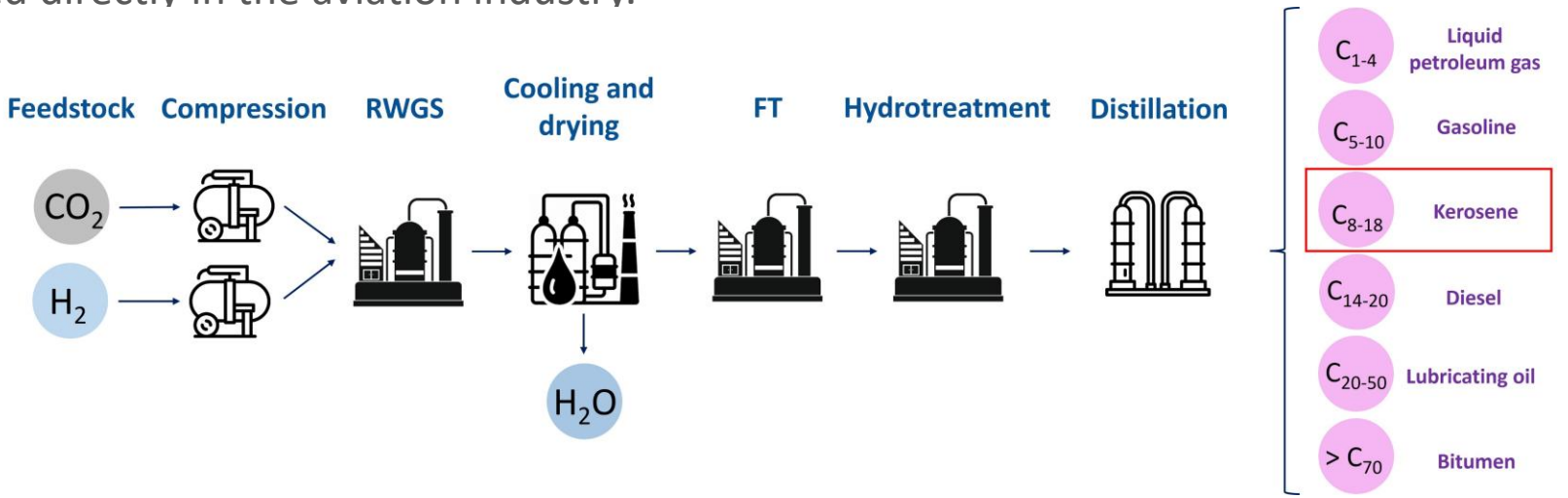
87.7 million
jobs supported worldide (aviation and related tourism). 11.3 million people worked directly in the aviation industry.

915 million tonnes
of CO_2 produced worldwide by flights.

Climate targets:

50%
By 2050, net aviation carbon emissions will be half of what they were in 2005.

Stabilise
From 2020, net carbon emissions from international aviation will be capped through carbon neutral growth.



Unfortunately, **conventional technologies** often suffer from **low selectivity** and **conversion** while **lacking energy efficiency**. Therefore, new technology solutions are required, in which the **rational design of catalytic materials and intensified sustainable processes** is a must.

Project Overview

Project dates
Starting date: May 2021
Duration: 3 years

Total project budget:
+3 Million EUR

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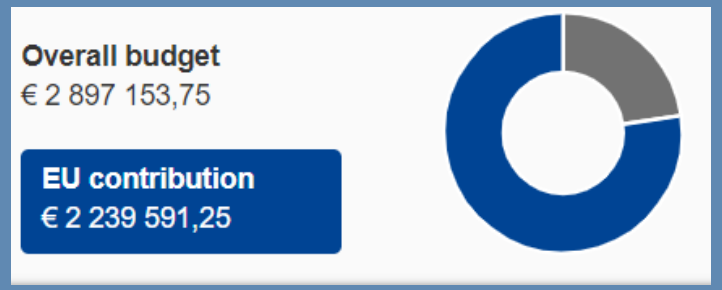
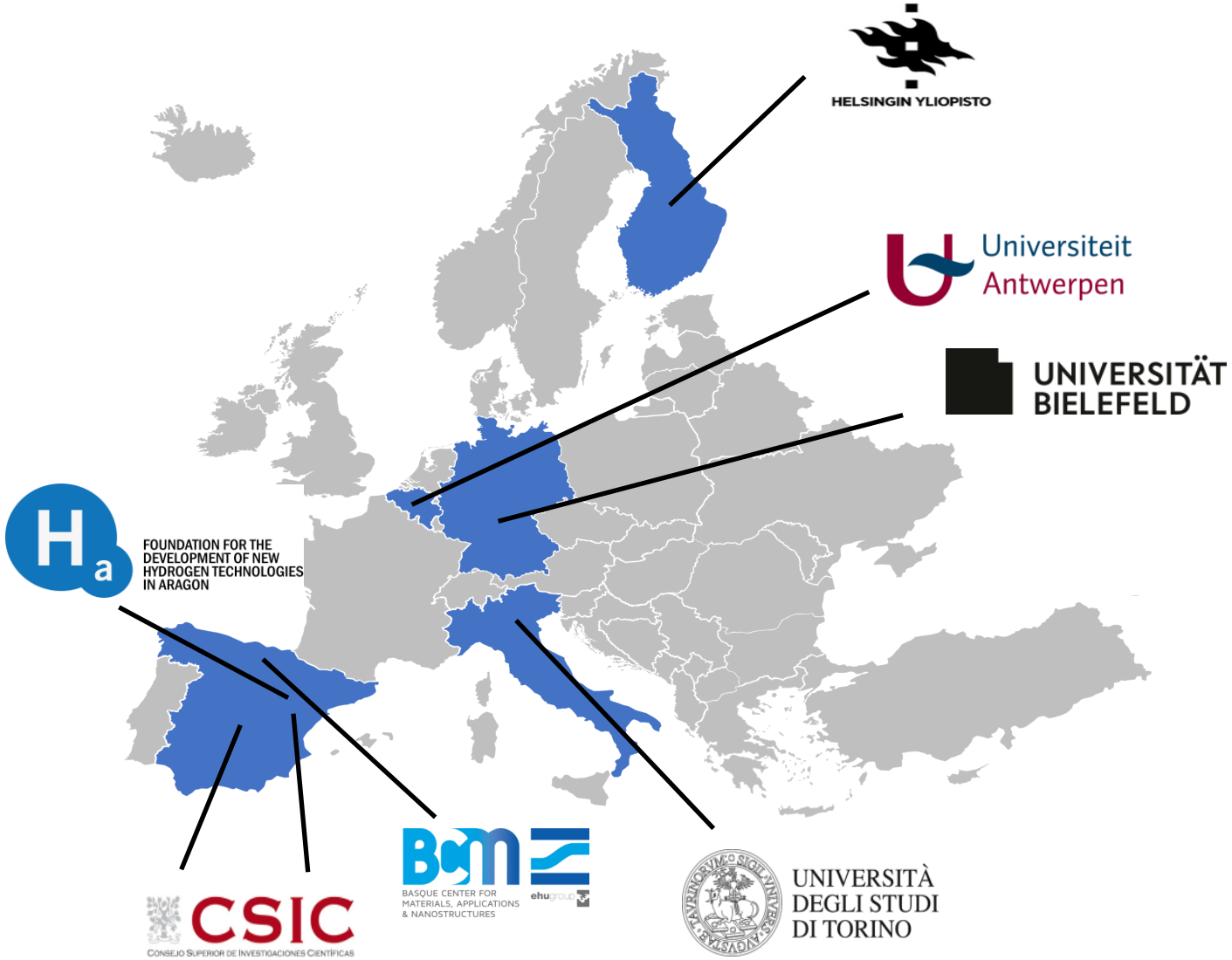
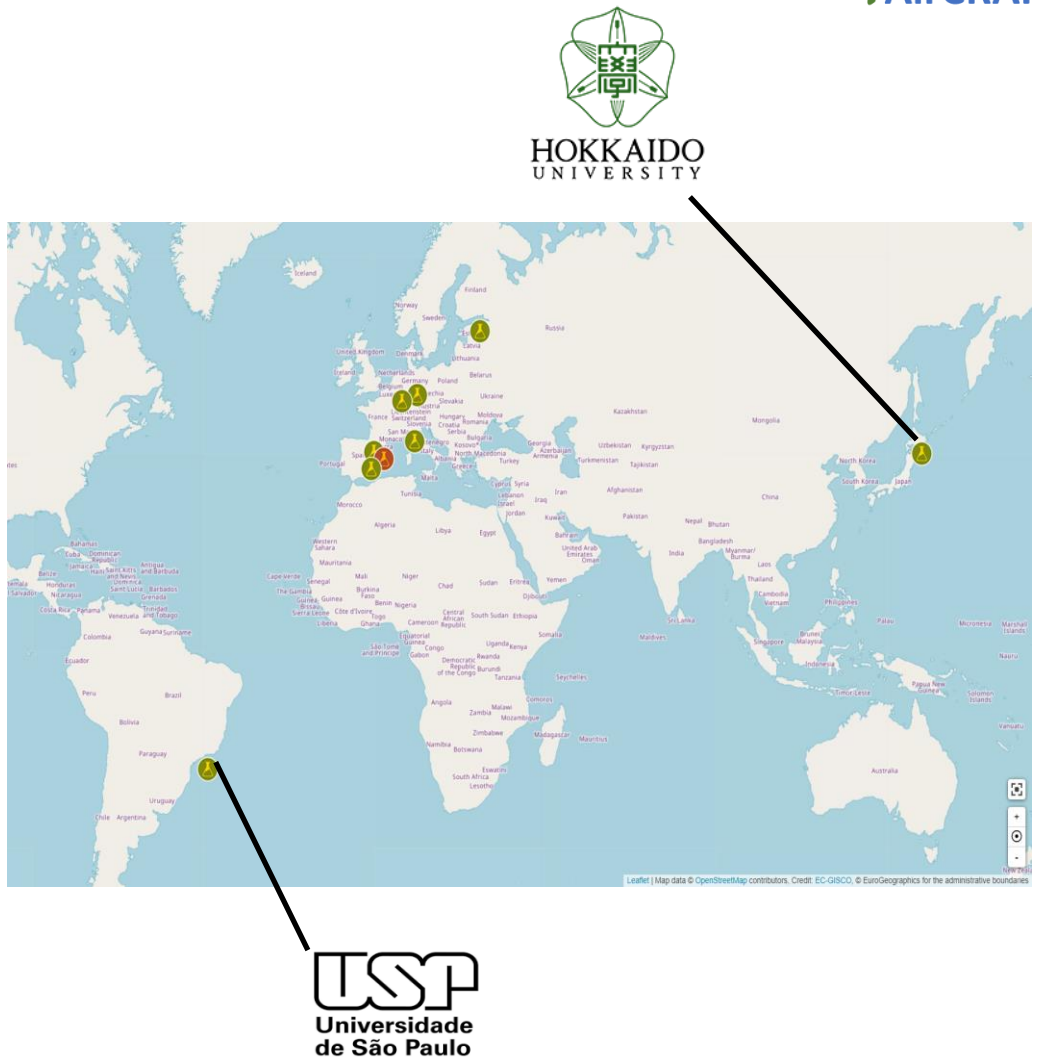
% stage of implementation
01/11/2023: 62 %
(extension of project request in process)



Partners

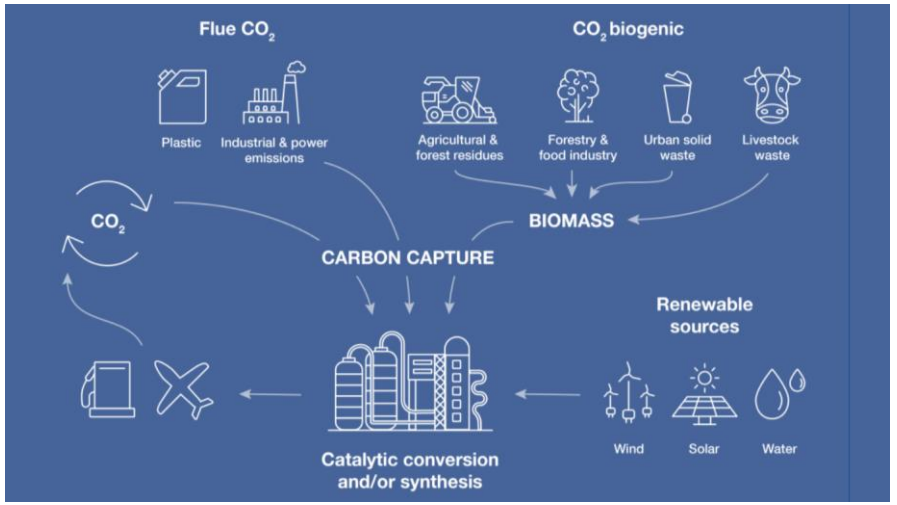

HELSINGIN YLIOPISTO
Universiteit Antwerpen
UNIVERSITÄT BIELEFELD
FOUNDATION FOR THE DEVELOPMENT OF NEW HYDROGEN TECHNOLOGIES IN ARAGON
CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
BCMaterials
BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
ehu group
UNIVERSITÀ DEGLI STUDI DI TORINO


HOKKAIDO UNIVERSITY
USP
Universidade de São Paulo

Project summary

Goal

Proof of the concept of a novel hybrid reactor including novel catalysts and linked lab-scale components/systems to produce sustainable long-chain hydrocarbons more efficient than existing approaches.



Water and carbon dioxide from biomass and industrial sources

Greener, milder and intensified liquid fuel production routes

Direct aviation use, storage and distribution in the existing infrastructures

This will be achieved by controlled synthesis and the unraveling of structure performance relationships both comprising the activity and the selectivity of the reaction towards molecules that are suitable as jet fuels.

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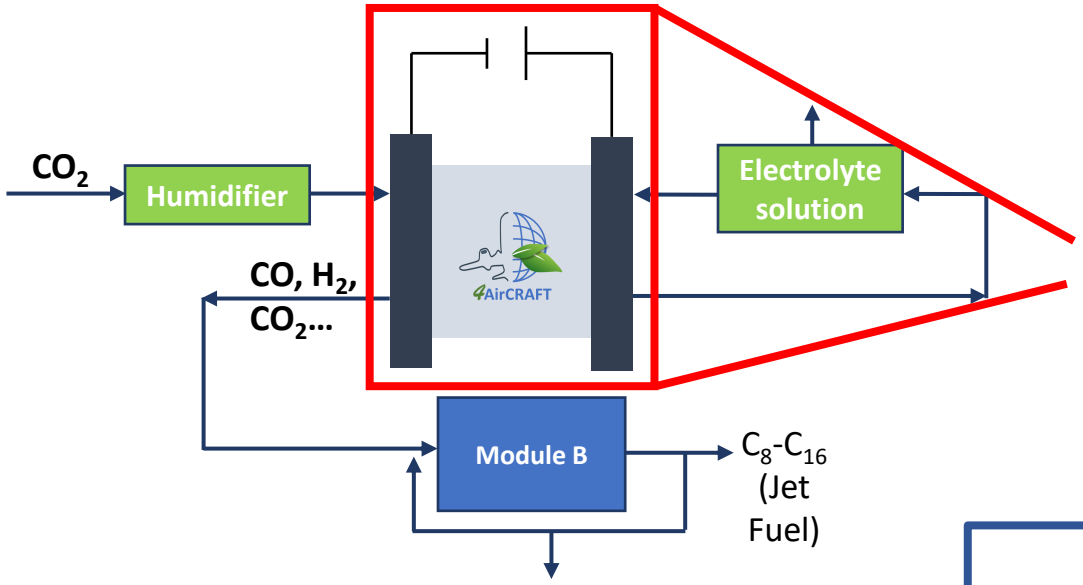
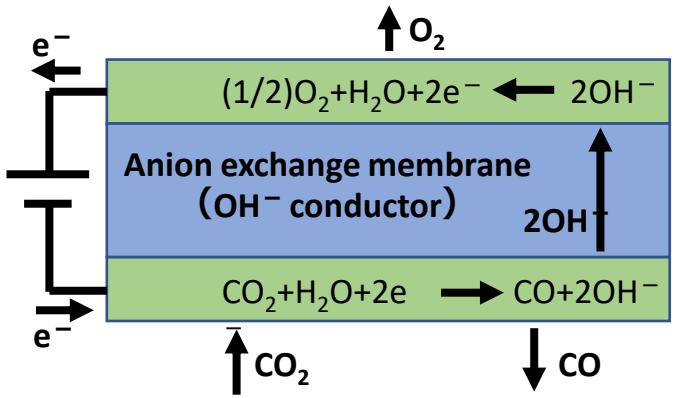
KEY ACTIVITY #1
CO_2 to CO: Electrocatalysts development

4AirCRAFT Cascade reactor – Strategy II - “syngas mediated”

Electrocatalysts for both CO_2 reduction and oxygen evolution, and anion exchange membrane that is stable under basic conditions are now being explored.





OER catalyst: Ni-Fe LDH, Ni-Al LDH

OH^- conductor : Mg-Al LDH

CO_2 RR catalyst: Zn-Al LDH

$$CO_2 + H_2O + 2\,e^- \rightarrow CO + 2\,OH^- \quad (1)$$

$$2\,OH^- \rightarrow H_2O + 2\,e^- + (1/2)\,O_2 \quad (2)$$

$$CO_2 \rightarrow CO + (1/2)\,O_2 \quad (3)$$

Lavered Double Hydroxide (LDH) based electrocatalyst

Prof. K. TADANAGA sensei

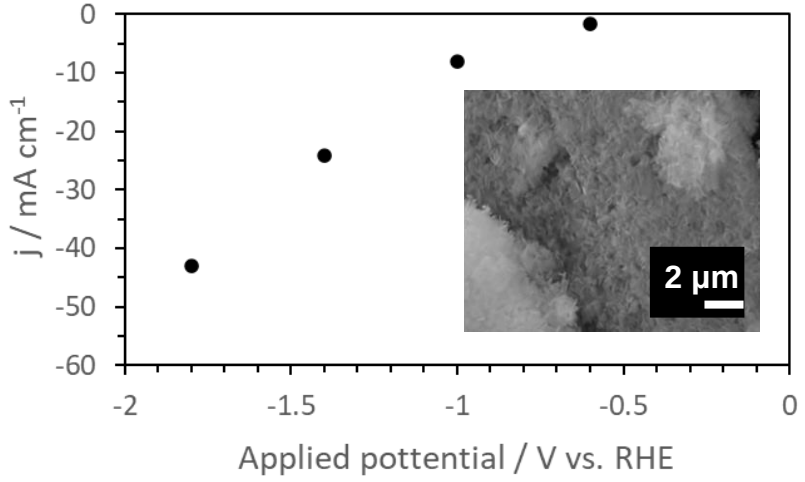
- Variety of metal combination[1]
- Large surface area [1]
- High OH- conductivity [2]
- Stability in alkaline solution [2]

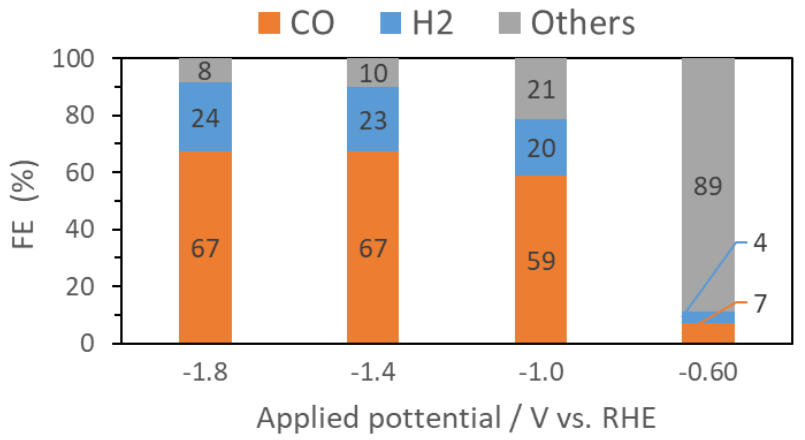
[1] C. I. Ezeh *et al.*, *Ultrason. Sonochem.* **2018**, *40*, 341;[2] K. Tadanaga *et al.*, *Adv. Mater.* **2010**, *22*, 4401.

Gaseous CO_2RR activity

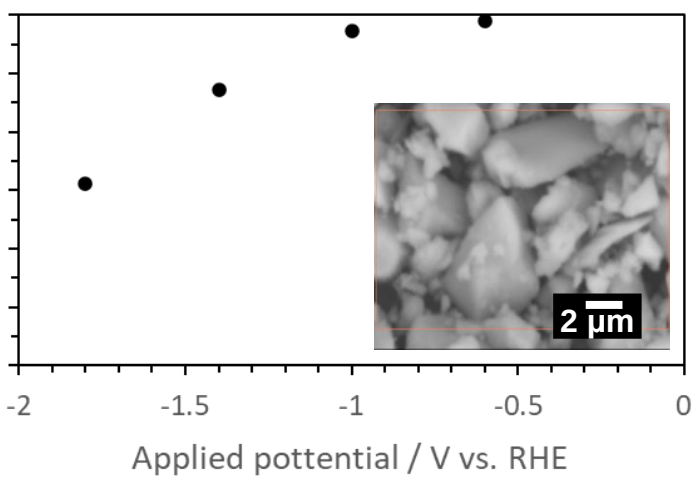
Current density (*j*) & Faradaic efficiency (FE)

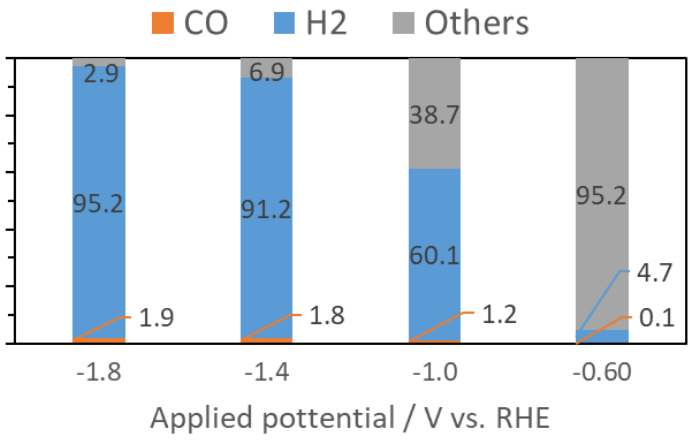
Zn-Al LDH



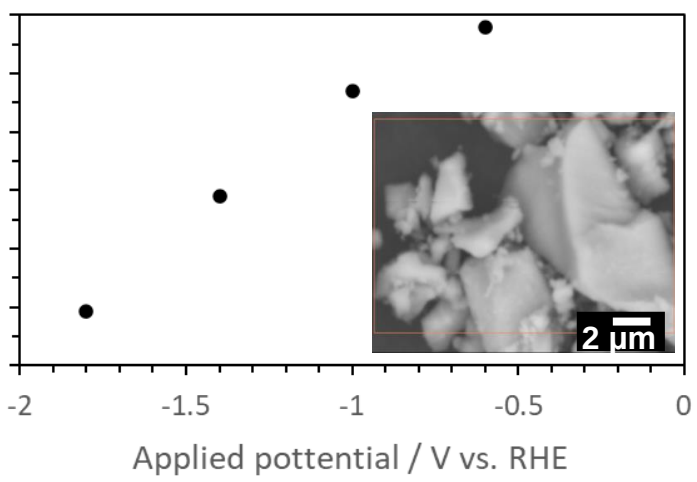


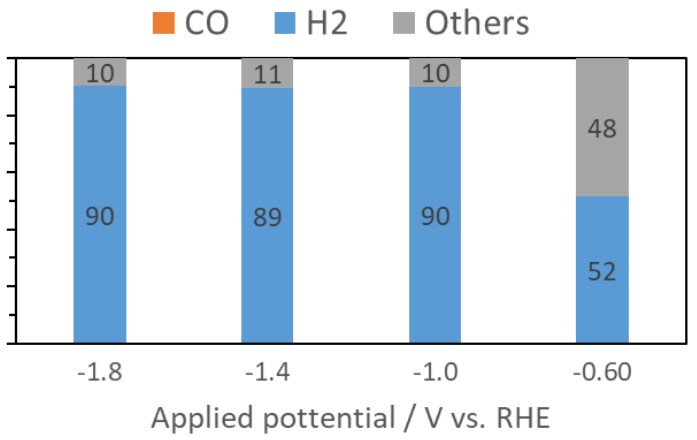
Ni-Al LDH





Ni-Fe LDH





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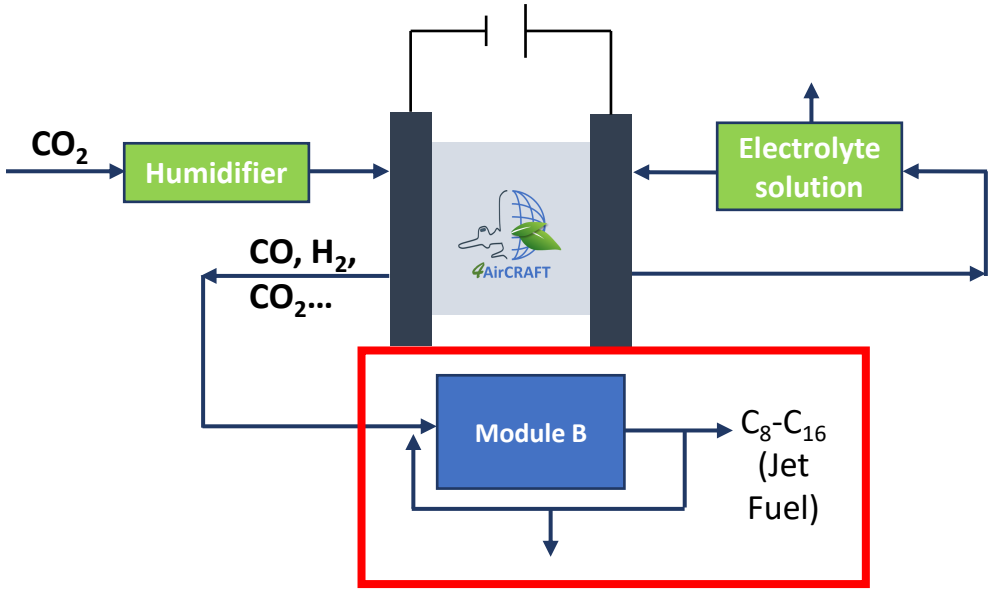
Air Carbon Recycling for Aviation Fuel Technology

KEY ACTIVITY #2
CO to Jet Fuels: Nanocatalyst development

4AirCRAFT cascade reactor – Strategy II - “syngas mediated”

Nanocatalysts Development: CO to Jet Fuels

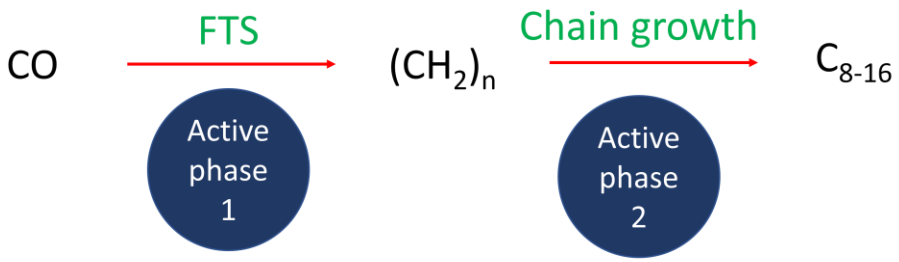


Zeolite based nanocatalysts; development and characterization

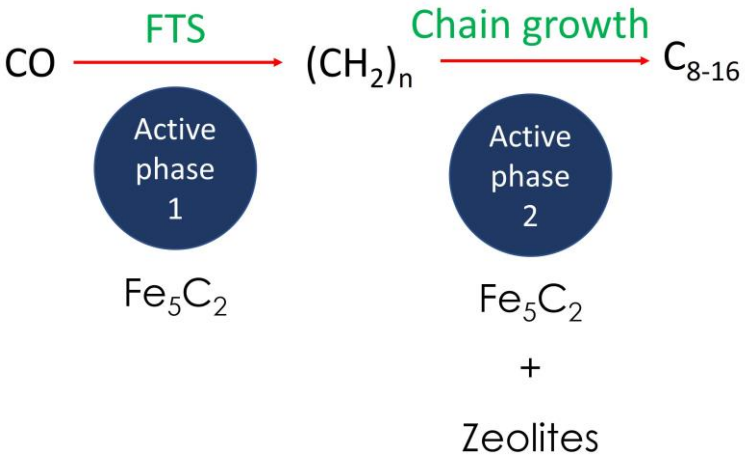
UNIVERSITY OF HELSINKI

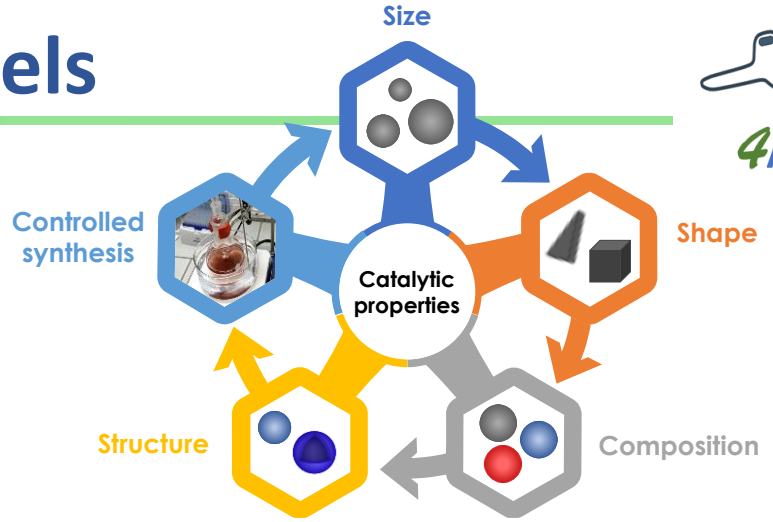
USP Universidade de São Paulo

Nanocatalysts Development: CO to Jet Fuels

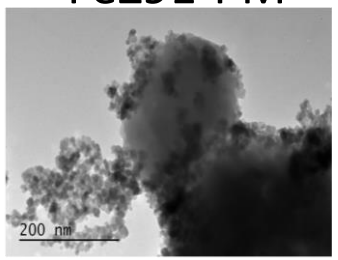


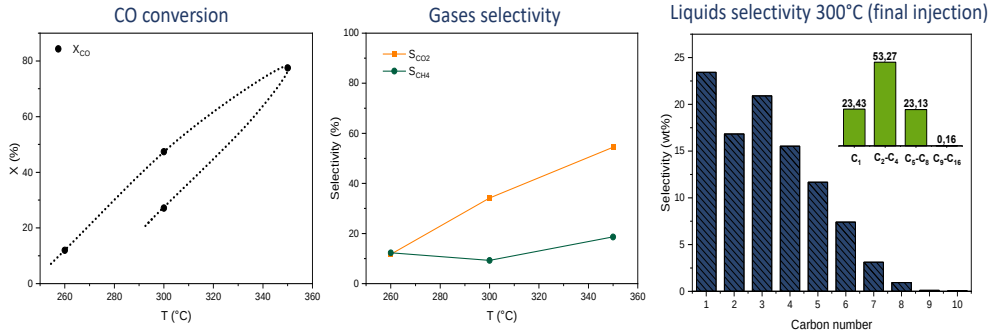
State-of-the-art catalysts: high temperatures and high pressure



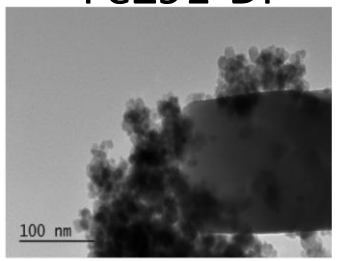


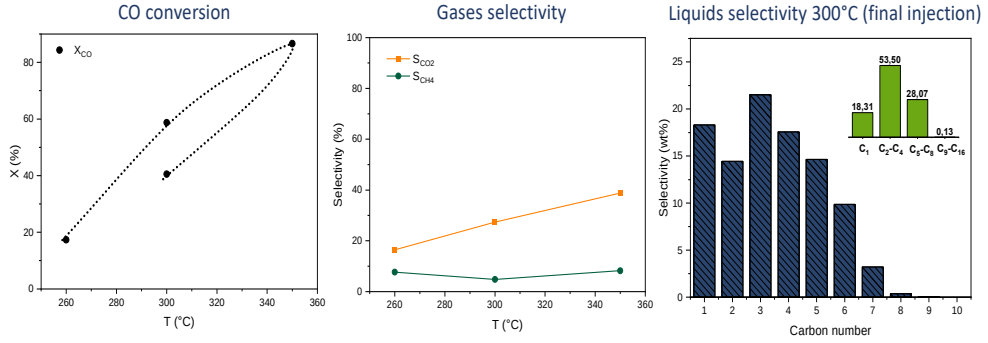
FeZ91-PM





FeZ91-DI





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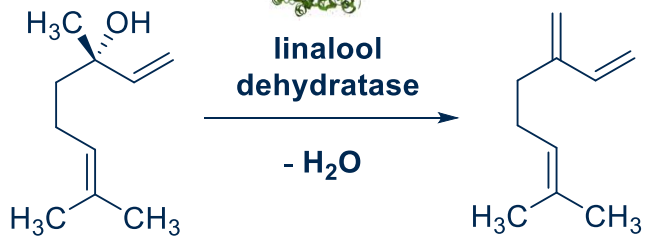
Air Carbon Recycling for Aviation Fuel Technology

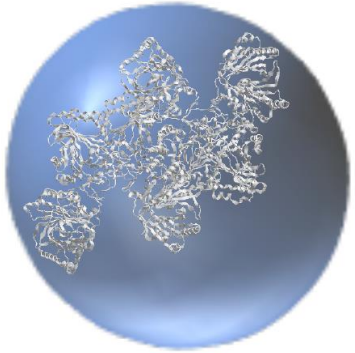
KEY ACTIVITY #3
Chemoenzymatic synthesis

Chemoenzymatic jet fuels synthesis

Prof. Dr. H. GRÖGER

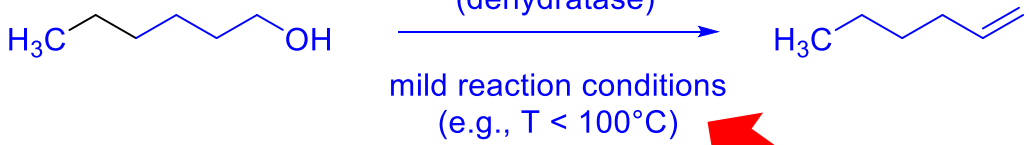
The goal: … or is it more a dream?



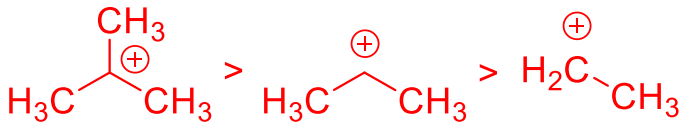


Biocatalysts known for tertiary alcohols,
but unknown for primary alcohols

But: dehydration of a tertiary and not primary alcohol!

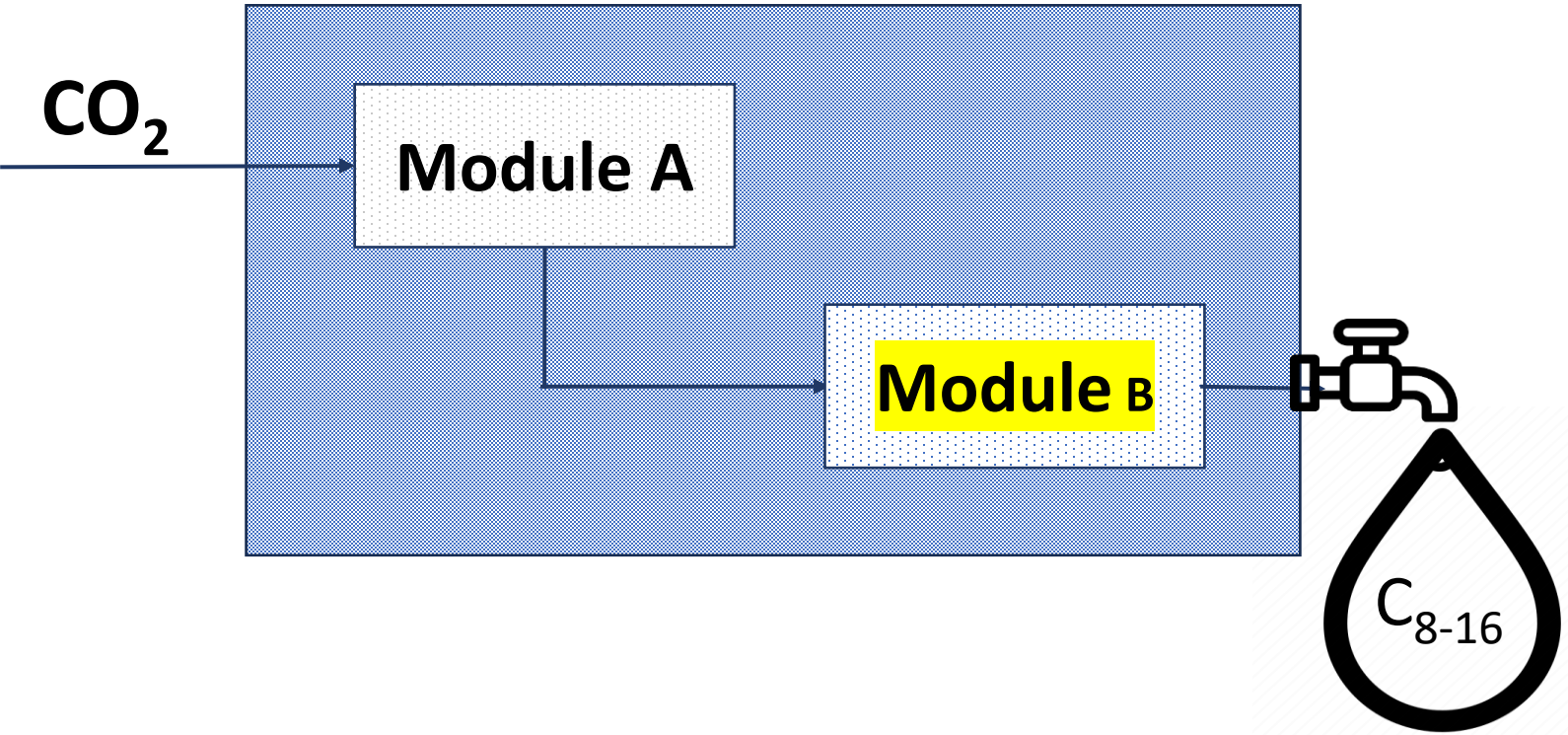


Stability of cations:



Chemocatalysts known for dehydration of primary alcohols,
but T>180 °C, mostly >250 °C

Biomimetic catalysts for dehydration of primary alcohols



PRODUCT
Precise synthesis and high yield of jet fuel

MILD CONDITIONS
Unprecedent low temperature

RATIONAL DESIGN
Hybrid catalyst integration & synergetic approach

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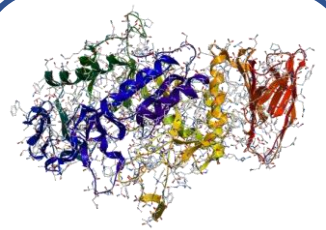
Air Carbon Recycling for Aviation Fuel Technology

KEY ACTIVITY #4
Advanced catalysts carriers

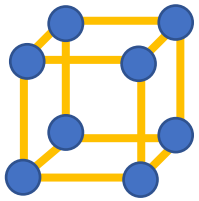
Metal-Organic Frameworks in 4AirCraft

Enzymes



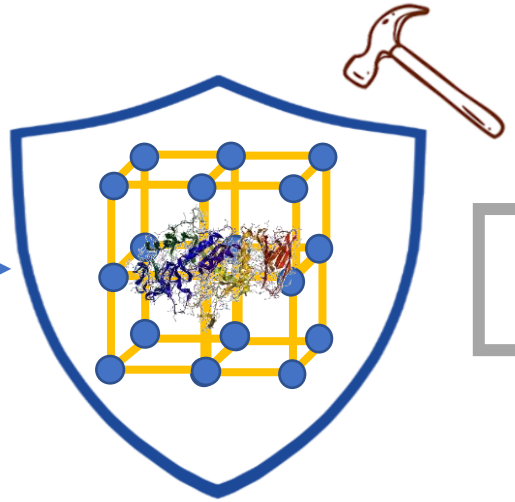
- Low operational stability
- Poor recyclability

MOFs

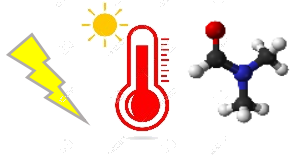


- 3D hybrid framework
- Chemical and thermal stability
- Synthesis under physiological conditions

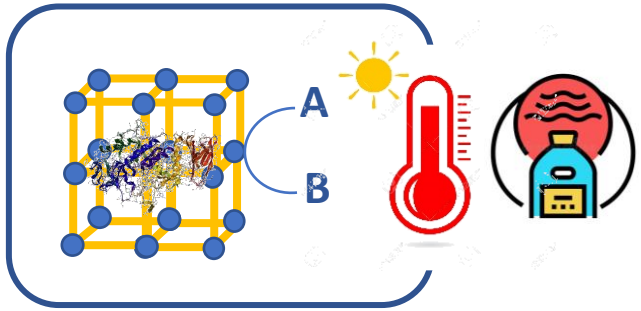
Biohybrid



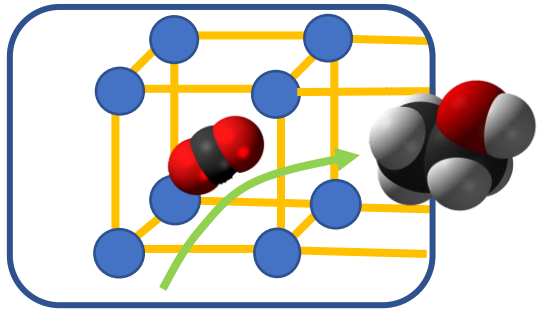
Protection



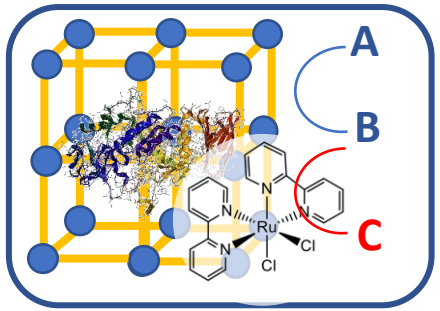
O_2



Functional at high T and organic solvents



Sieving effect of the porous framework



Coupling of Biocatalysts and Chemocatalyst

Improvement of conversion, selectivity, stability

Nano → Macro scale

Prof. S. WUTTKE

ikerbasque
Basque Foundation for Science

BCMaterials
BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
ehu group

Dr. J. GURAUSKIS

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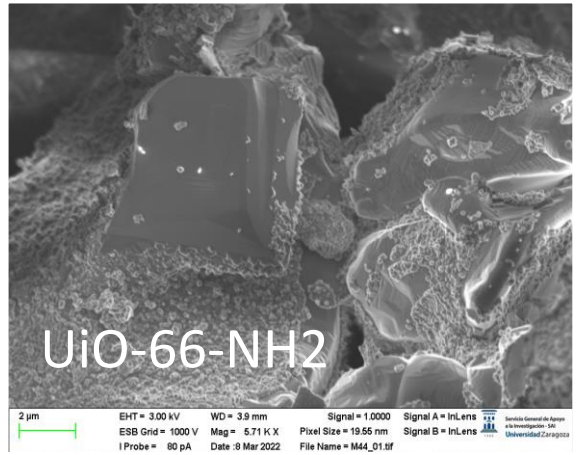
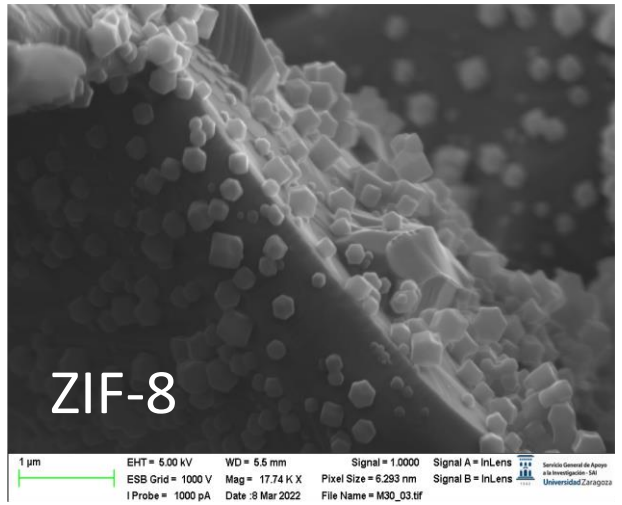
Metal-Organic Frameworks

Hierachical porous scaffolds





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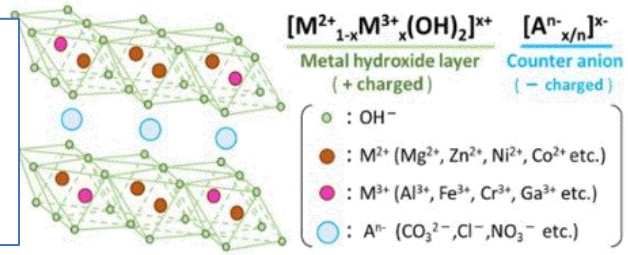
Air Carbon Recycling for Aviation Fuel Technology

KEY ACTIVITY #5
Advanced Characterization

In situ and operando characterization

IR spectroscopy

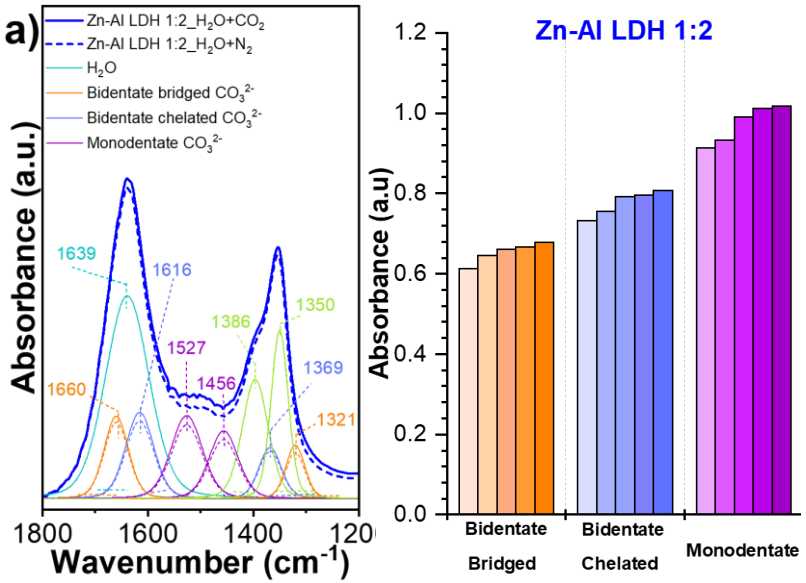
Electrocatalyts
ATR-IR spectroscopy on LDH

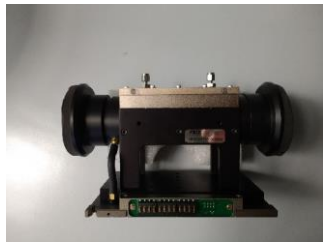


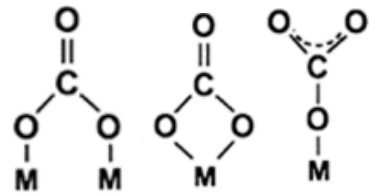
$[M^{2+}_{1-x}M^{3+}_{x}(OH)_2]^{x+}$ Metal hydroxide layer (+ charged)

$[A^{n-}_{x/n}]^{x-}$ Counter anion (− charged)

: OH^-
: M^{2+} (Mg^{2+}, Zn^{2+}, Ni^{2+}, Co^{2+} etc.)
: M^{3+} (Al^{3+}, Fe^{3+}, Cr^{3+}, Ga^{3+} etc.)
: A^{n-} (CO_3^{2-}, Cl^-, NO_3^- etc.)

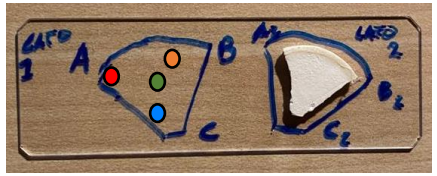


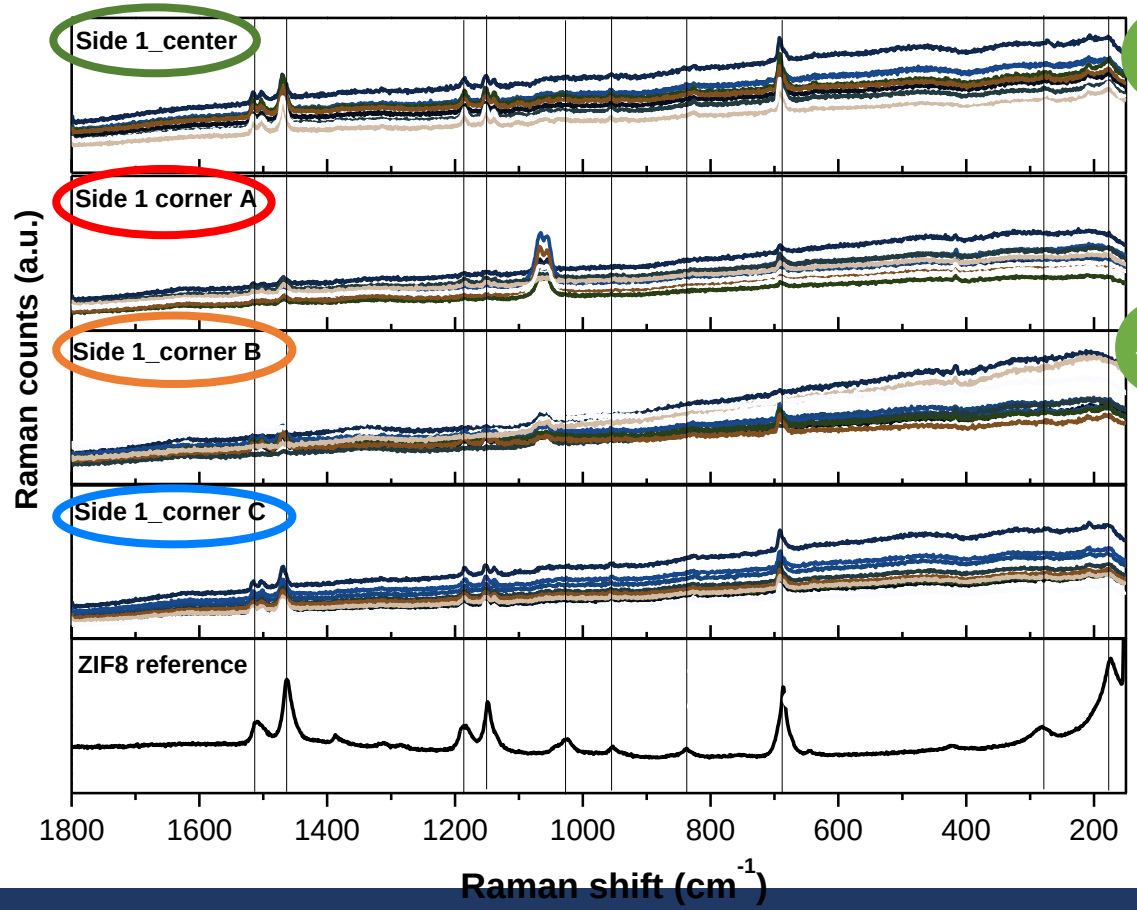




Raman spectroscopy

Functionalized Catalyst carriers
Raman spectroscopy on composites materials





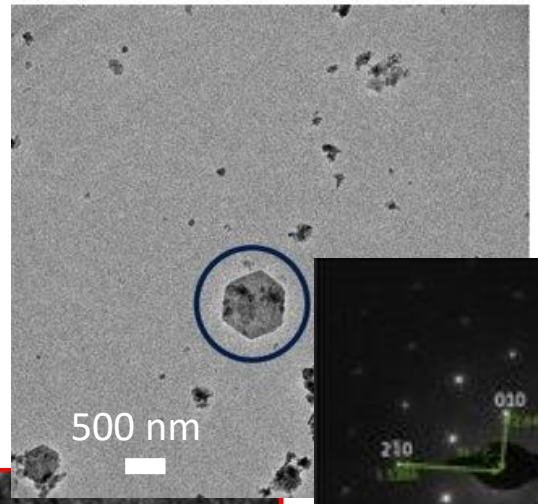
Detection of composite material

Detection of composite material

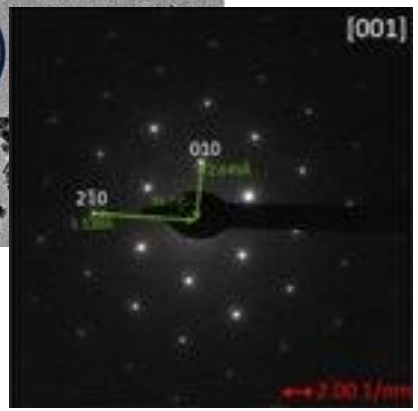
Dr. F. BONINO

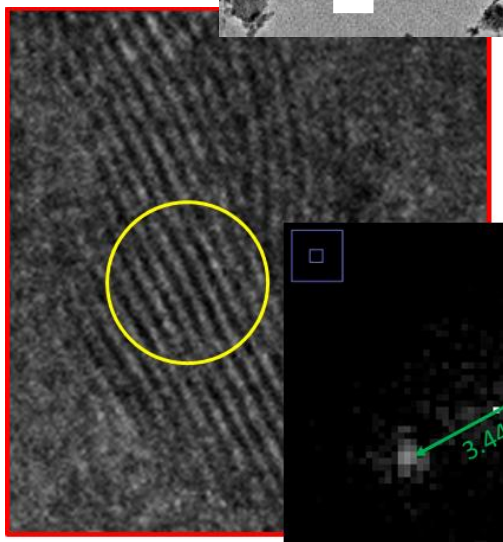
UNIVERSITÀ DI TORINO

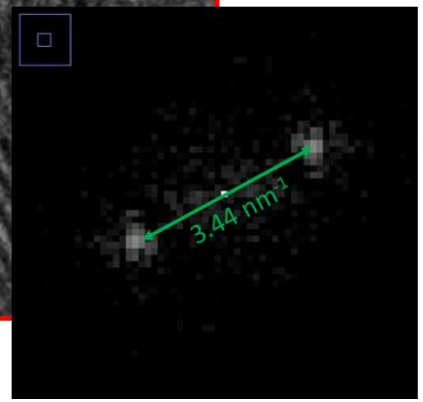
Morphology, Composition, cristal structure
by means of transmission electron microscopy



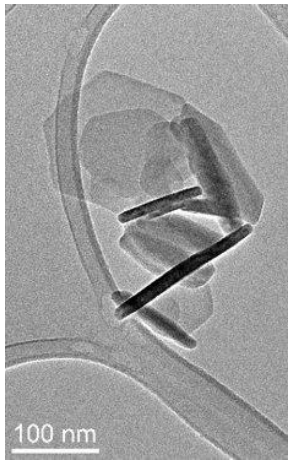
LM-TEM and ED for crystal structure



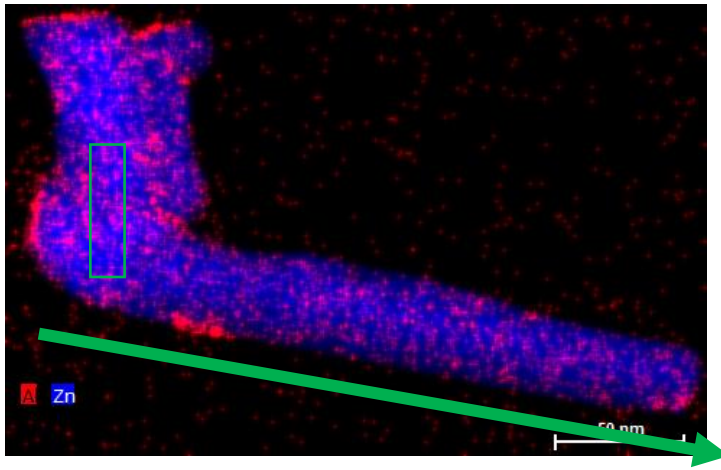




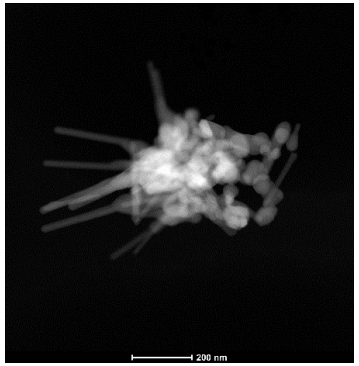
High resolution TEM and FFTS for interlayer spacings



BF-TEM of the morphology

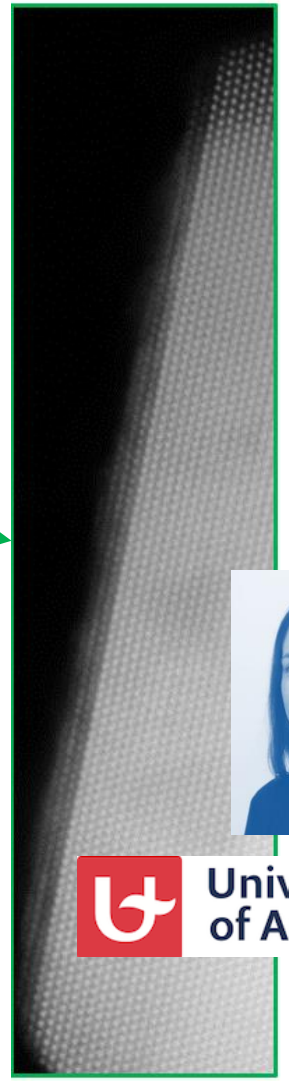


EDX analysis of the composition



LM-HAADF-TEM of the morphology

HAADF-STEM atomic resolution imaging of crystal structure, layers, defects



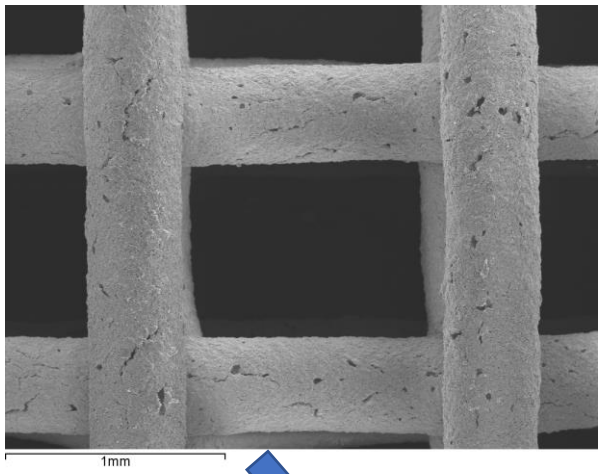
University of Antwerp

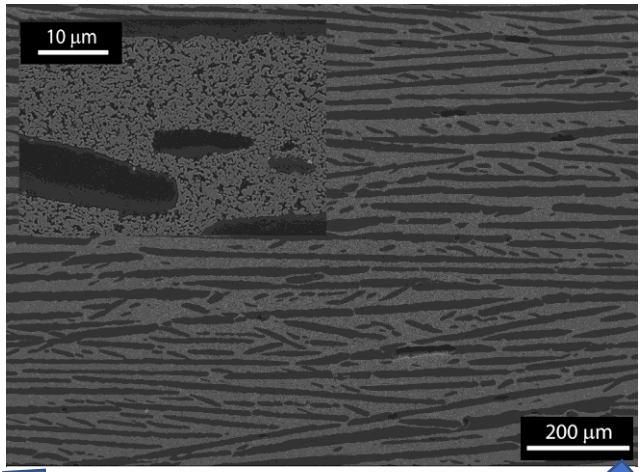
4AirCRAFT

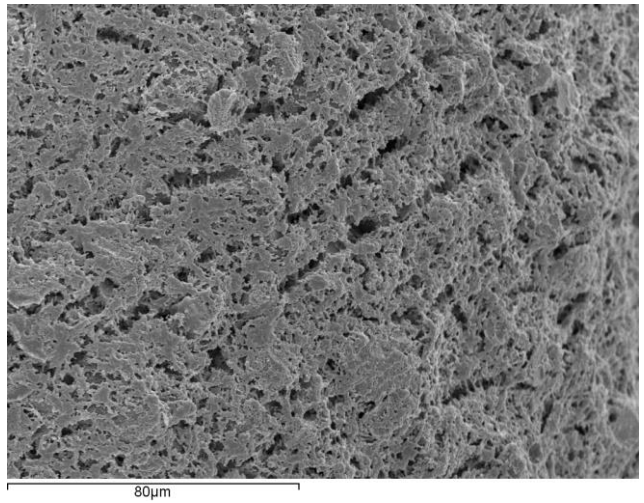
Air Carbon Recycling for Aviation Fuel Technology

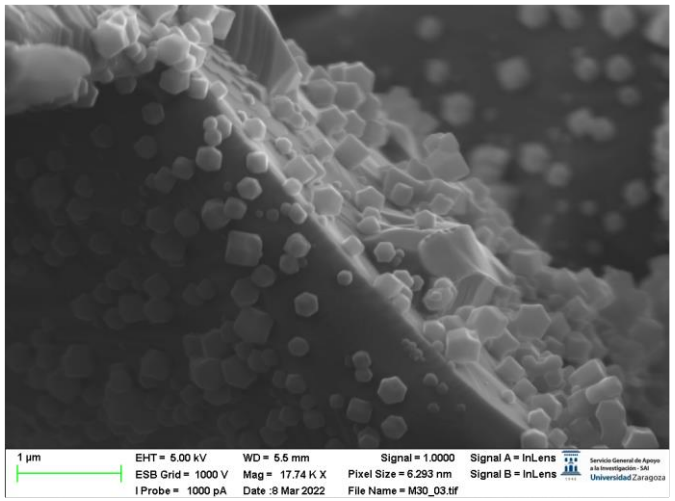
KEY ACTIVITY #6
Additive manufacturing - reactors

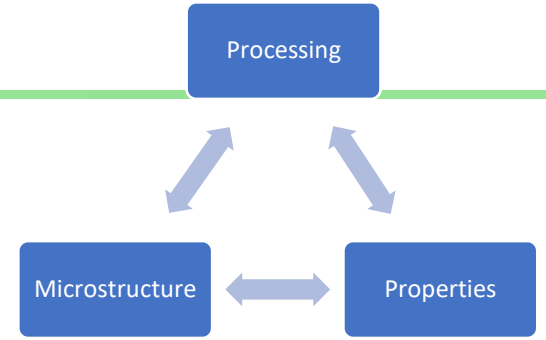
Components of the reactor











Dr. J. GURAUSKIS

araid
FUNDACIÓN AGENCIA ARAGONESA PARA LA INVESTIGACIÓN Y EL DESARROLLO

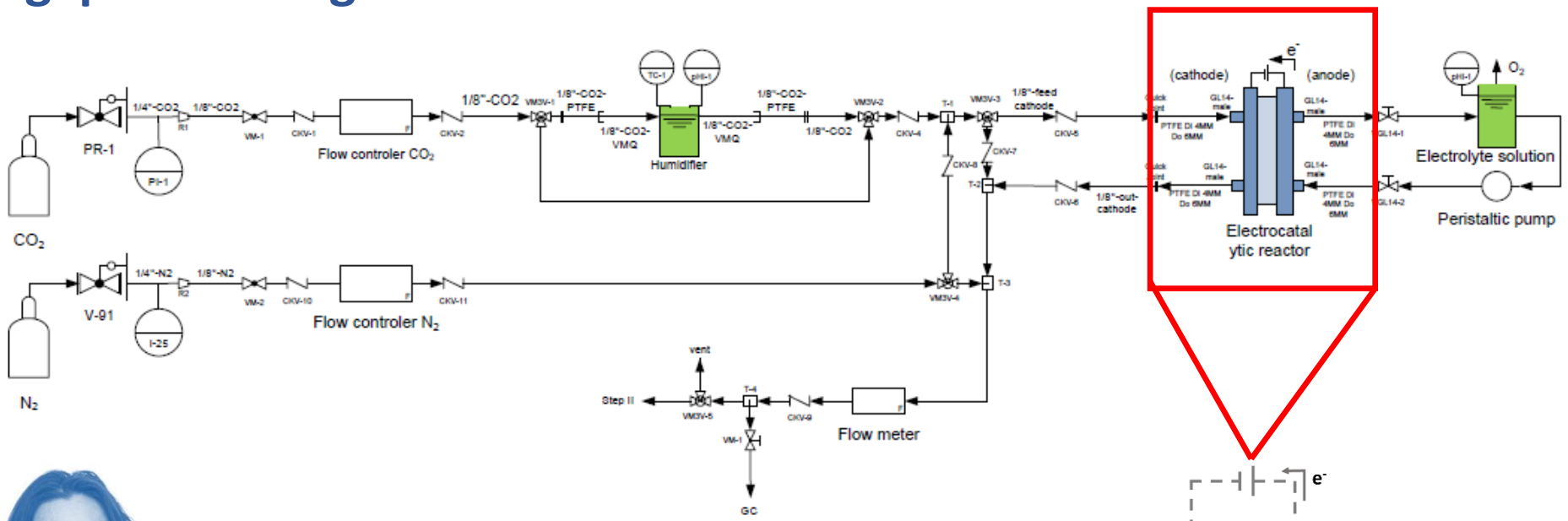
INMA
INSTITUTO DE NANOCIENCIA Y MATERIALES DE ARAGÓN

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

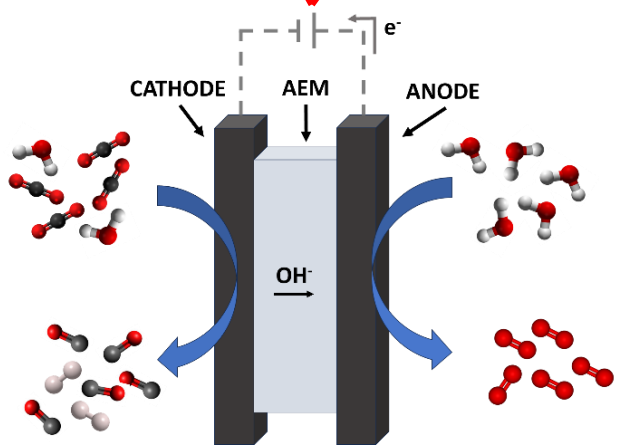
Next steps:
Proof of the concept

Proof of concept “electrochemical module”

Zero-gap cell configuration – CO2RR Test bench

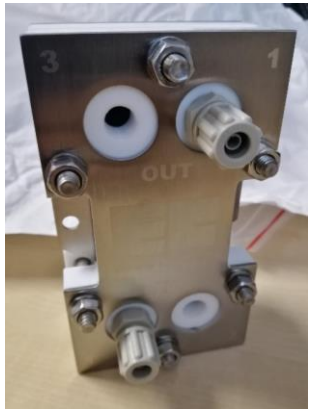


Dr. V. GIL

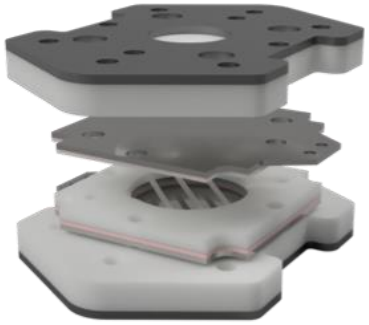


Zero-gap for the CO2RR

Proof of concept “electrochemical module”



Commissioning module
-single cell-



Initial module design
-single cell-

- ✓ Faraday Efficiency **FE**
- ✓ Lifetime
- ✓ LCA

Summary

4AirCRAFT – Research Activities

Materials

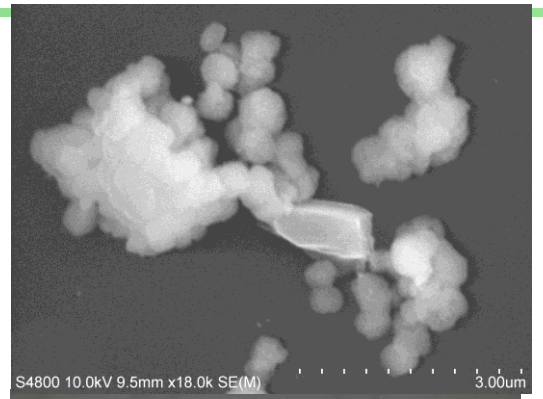
- Electrocatalyst
- Chemocatalysts
- Biocatalysts and Biomimetic catalysts
- Structural and mechanistic investigations

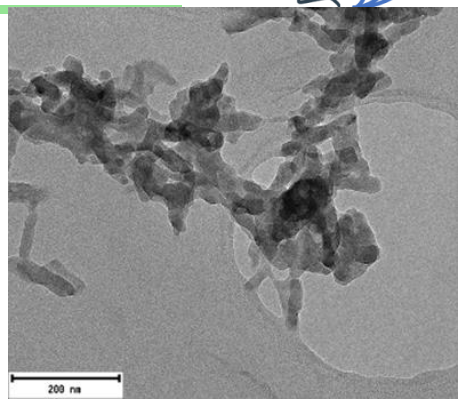
Components

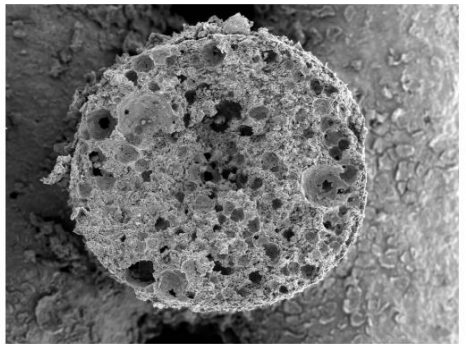
- Membranes and Electrodes
- Advanced Catalysts Carriers
  MOFs and nano→meso→macro strctured and functionalized scaffolds)
- Structural and mechanistic investigations

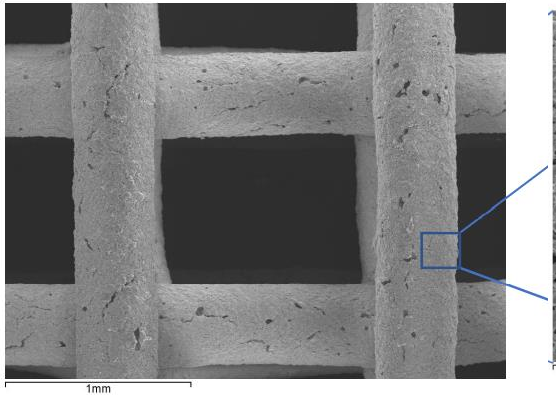
Reactor

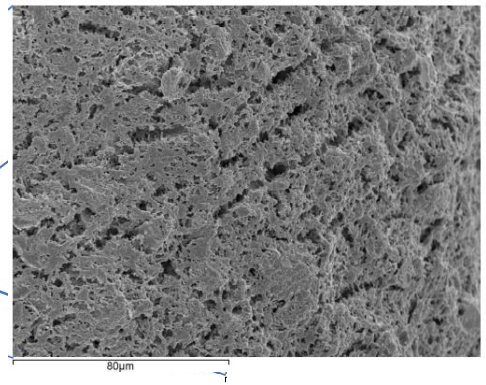
- Reactor design-Process Intensification
- Structural and mechanistic investigations
- Proof of the concept and Life Cycle Assessment





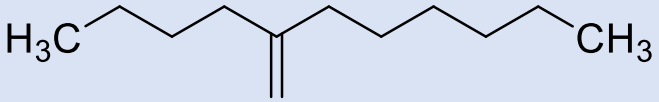


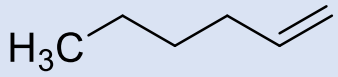


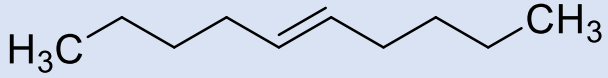


Potential target molecules being accessible by 4AirCRAFT

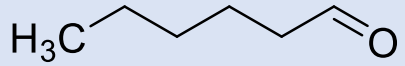
alkenes

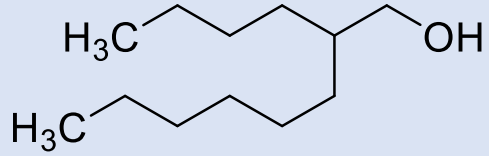




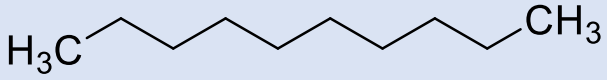


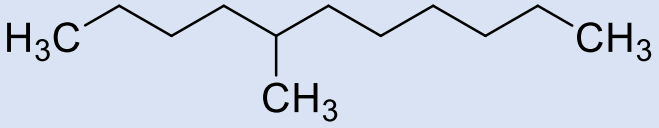
oxo-products



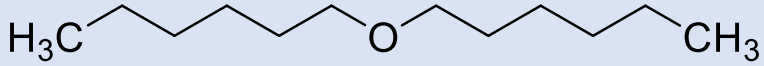


alkanes





dialkyl ethers



4AirCRAFT

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