Università degli Studi Guglielmo Marconi

Laboratory USGM

Department of Engineering Science (DES)

High temperature conditioning and solid oxide fuel cell: experimental tests and analysis

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Outline

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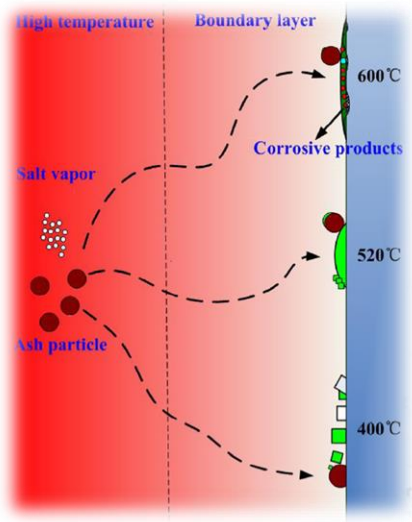
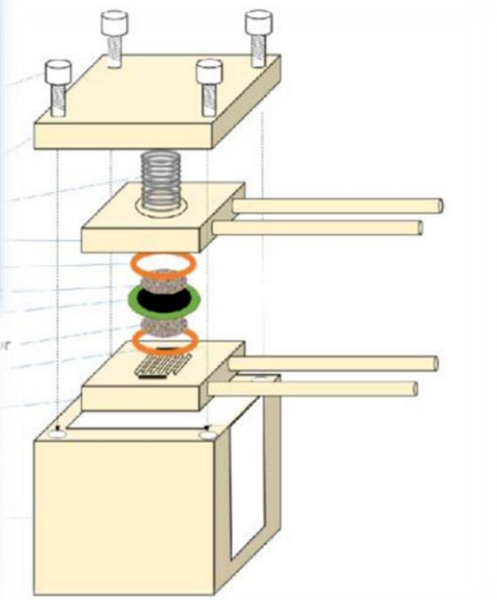
- Study cases
  - ZnO sorbents
  - Ni-based catalysts
  - Solid oxide fuel cell (SOFC)
- Final remarks





Research team

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Graduate Research Fellow

Project Zephyrus

Project GICO

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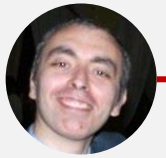
Post-Doctoral Research Fellow

Arda Hatunoglu
Graduate Research Fellow

Prof. Fontana
Responsible for laboratory teaching

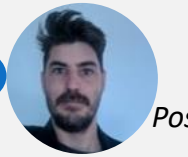
Stefano Innocenti
Laboratory Technician

Andrea Maresca
Laboratory Engineer



Project SO-FREE

Prof. Bocci
Scientific head and project coordinator



Luca Del Zotto
Project Manager and Post-Doctoral Research Fellow

Project RE-OPEN

Project BLAZE

Roberta Caponi
Graduate Research Fellow

Vera Marcantonio
Post-Doctoral Research Fellow

Project LIFE3H

Collaborations agreements with joined staff and equipment

Thanks to agreements with other universities and research centers the staff and the equipment of the lab is **integrated in larger network**

Alessandro Dell'Era for chemical material experimentation and characterization (within DSI/USGM-SBAI/Sapienza agreement). **Emanuele Habib** for thermal processes integration in the SOFC model (within DSI/USGM-DIAEE /Sapienza agreement) Arda Hatanoglu (DIAEE PhD student).

Andrea Di Carlo for exchange of data and USGM analysis of their continuous micro reactor and gasifier model (DSI/USGM-DIIE/L'Aquila e Project BLAZE, GICO, AIRE).

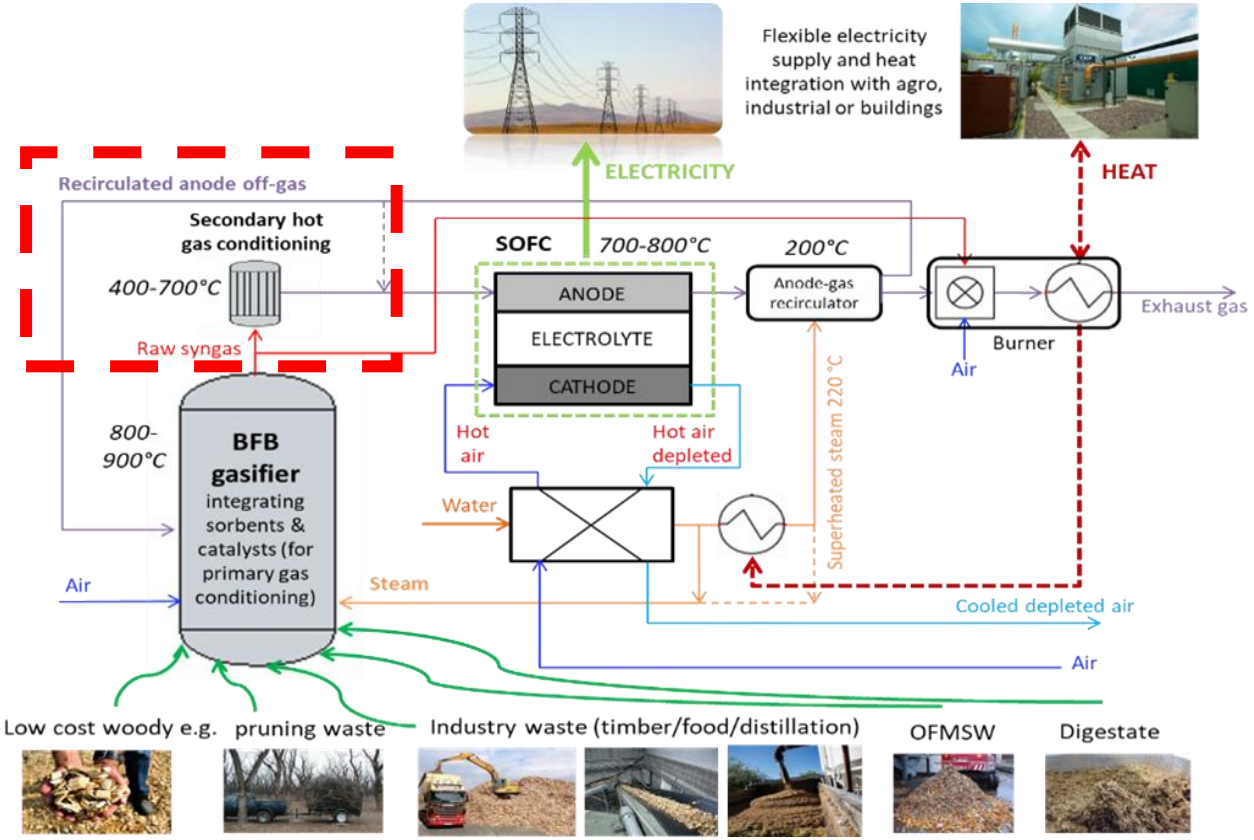
Marcello De Falco and Vera Marcantonio for system simulation (via ASPEN) of BLAZE and GICO.

Stephen Mc Phail and Andrea Monforti for SOFC test bench and SOFC model and **Stefano Stendardo** for sorbents/catalyst and CO_2 capture (ENEA-USGM e Project BLAZE, GICO, ZEPHTYRUS**). Donatella Barisano** for biomass and thermochemical process characterizations

Vincenzo Mulone, Simone Sanna, Antonello Tebano for exchange data and USGM analysis of their pyrolizer and exchange data among the SOFC materials UTV development and the USGM button cells test rig.

Introduction

- Raw syngas: H_2, CH_4, CO and CO_2; organic (tar, naphthalene, toluene) and inorganic (H_2S, HCl and alkali metals) compounds.
- Solid oxide fuel Cell (SOFC): Low tolerance to contaminants.
- High temperature conditioning: Contaminant capture and tar conversion.
- Material characterization.



project BLAZE

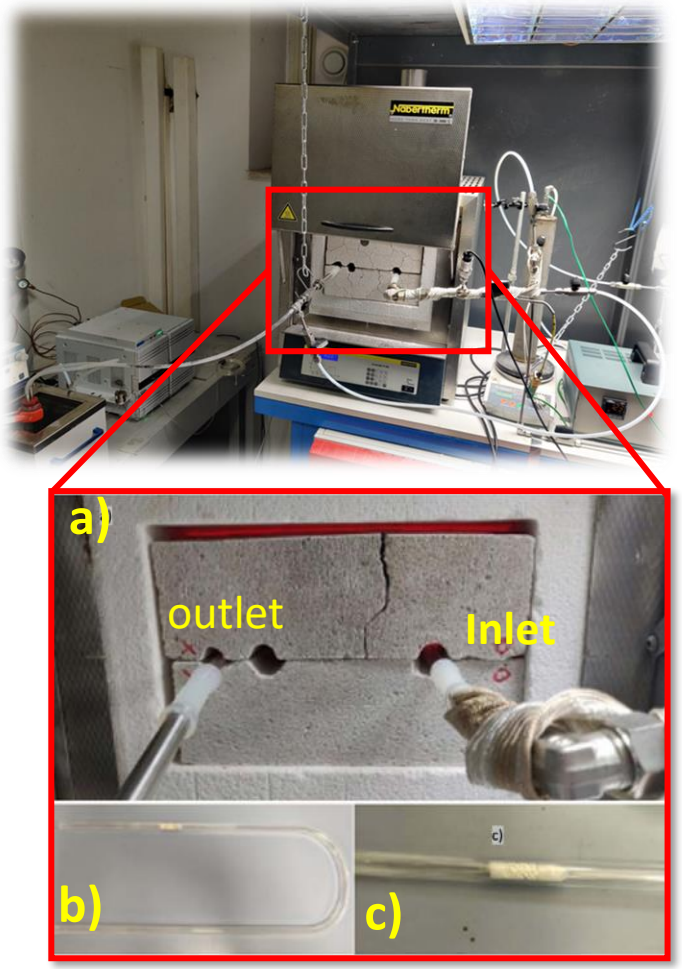
RemoteLAB

Unimarconi

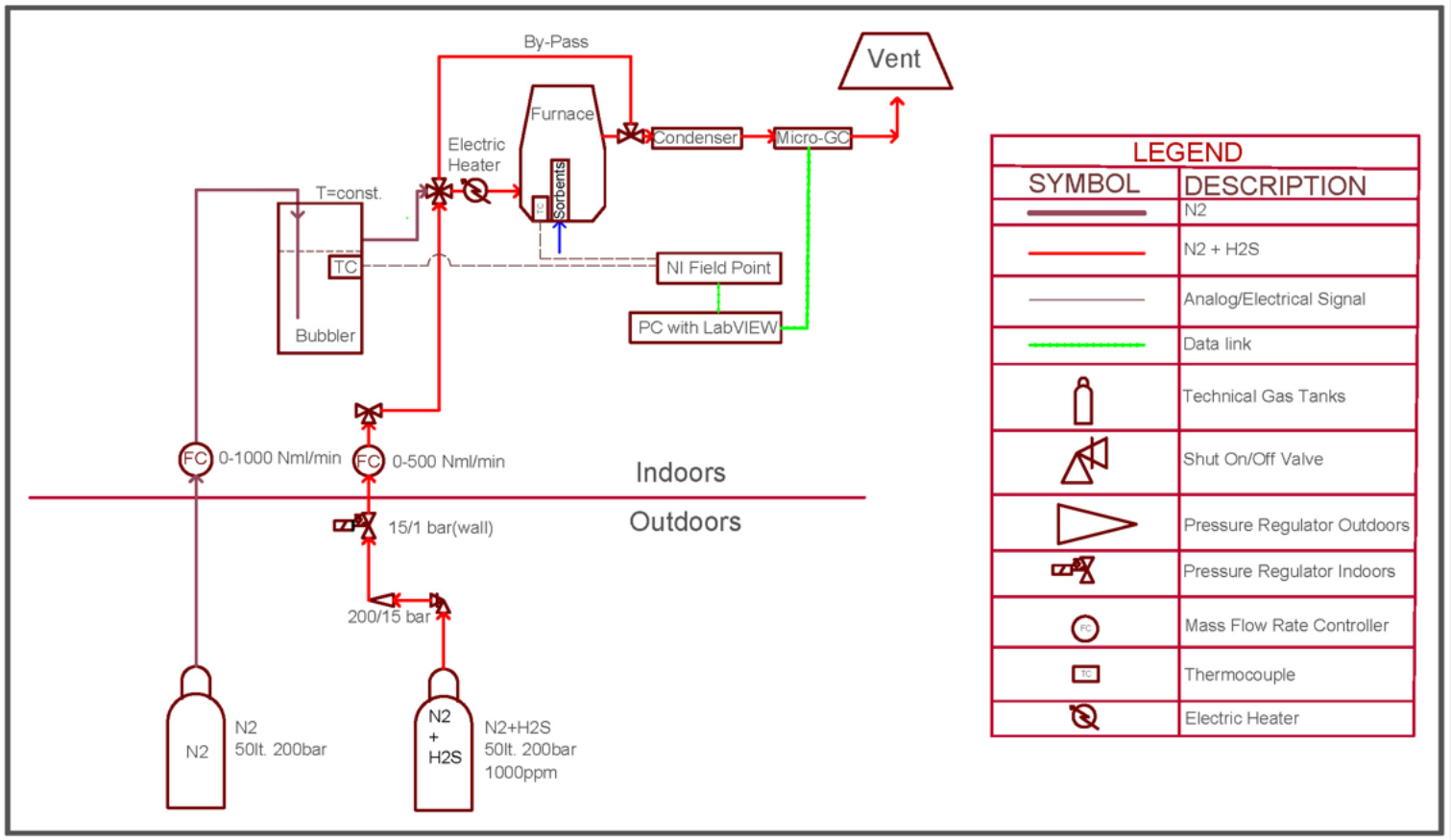
Study cases

- ZnO sorbents
- Ni-based catalysts
- Solid oxide fuel Cell (SOFC)

HTC: ZnO sorbents



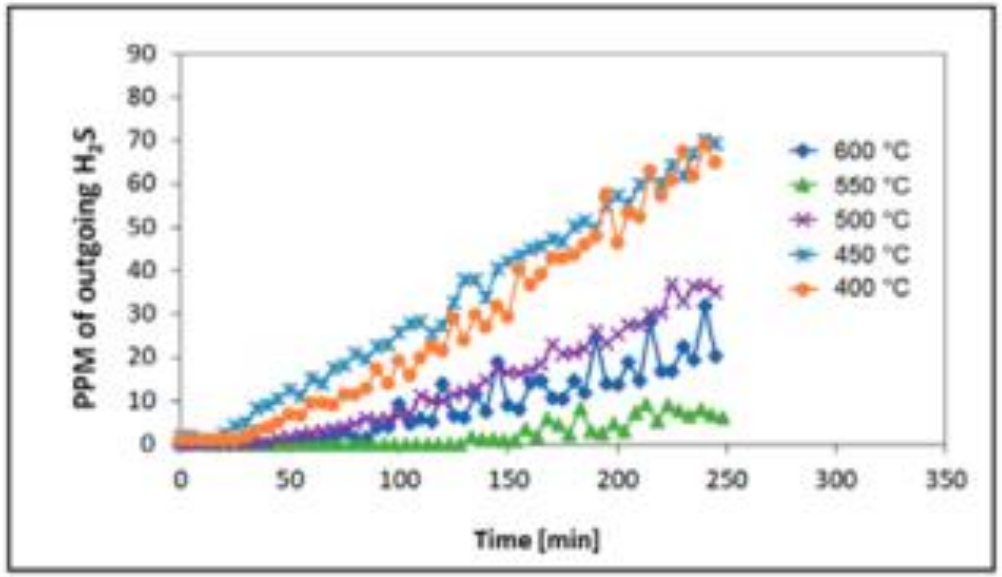
(A. Hatunoglu et al.)
(10.3390/en14238019)



Setup for sorbents testing

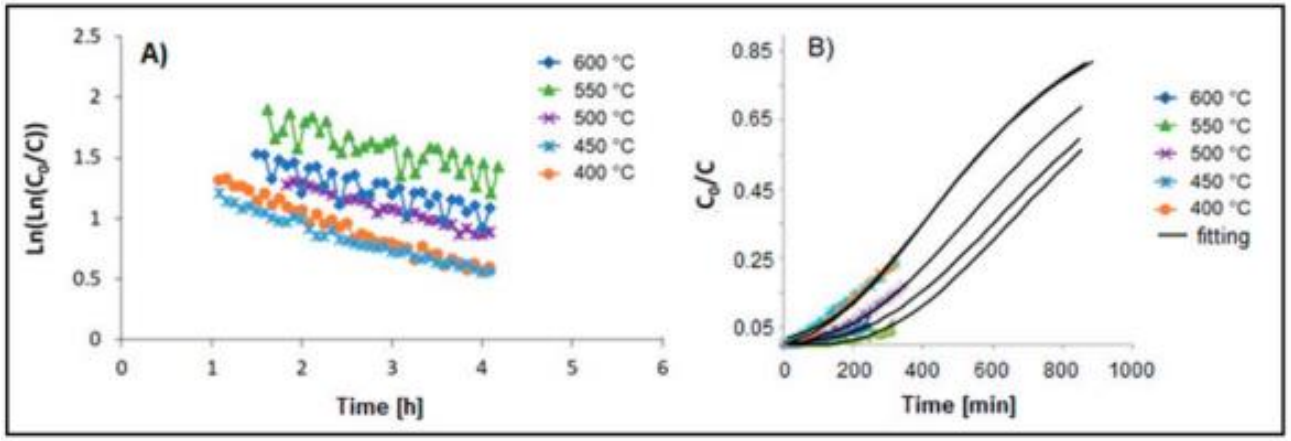
a) Muffle Furnace
b) Quartz (SiO_4) tube with ZnO sorbent
c) Close up picture of the ZnO reactor.

HTC: ZnO sorbents



$$ZnO_{(s)} + H_2S_{(g)} \leftrightarrow ZnS_{(s)} + H_2O_{(g)}$$

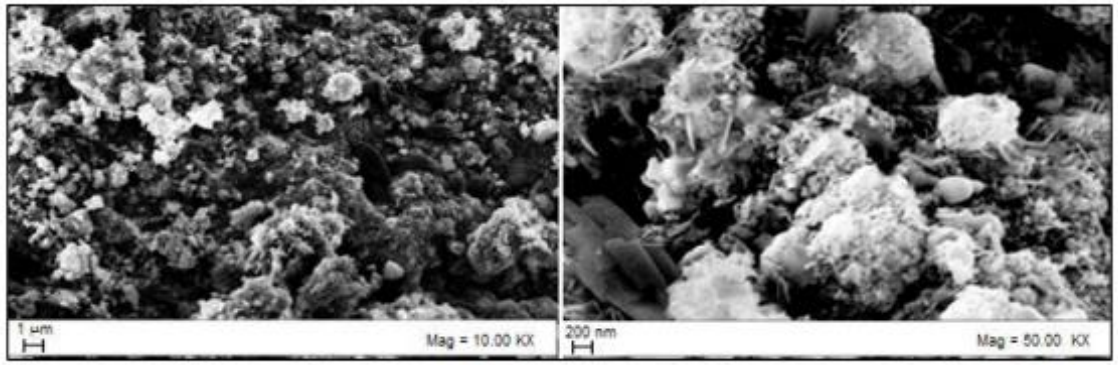
Outlet H_2S concentration vs time at different temperatures (400, 450, 500, 550, and 600 °C) with N_2 being the gas matrix.

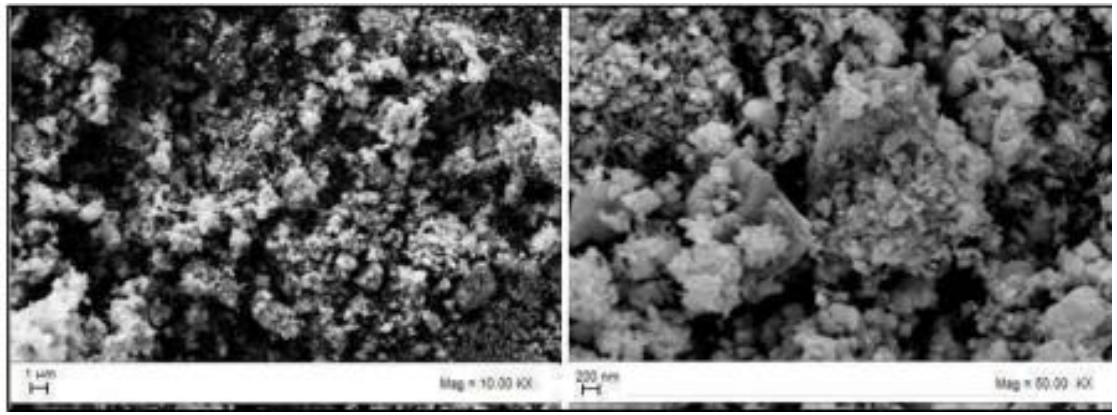


(Left) Linear trend of ln(ln(C0/C)) vs Time for a temperature ranging from 400 °C to 600 °C; (right) Breakthrough curves fitting results with a bed length equal to 1.5 cm and GHSV equal to 25,000 h^{-1}.

HTC: ZnO sorbents

SEM micrographs of ZnO sorbent **before and after** adsorption.

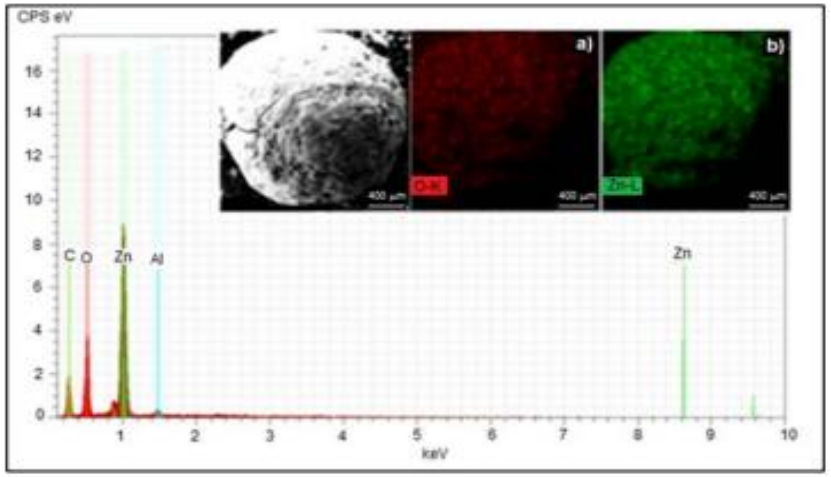


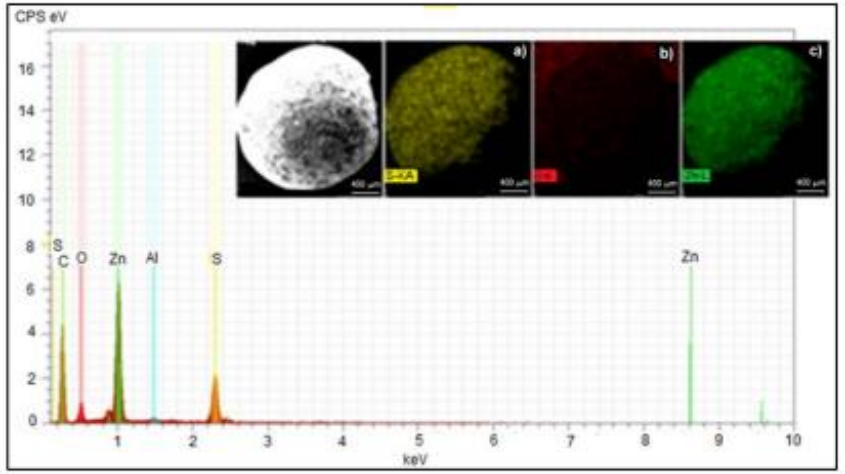


before

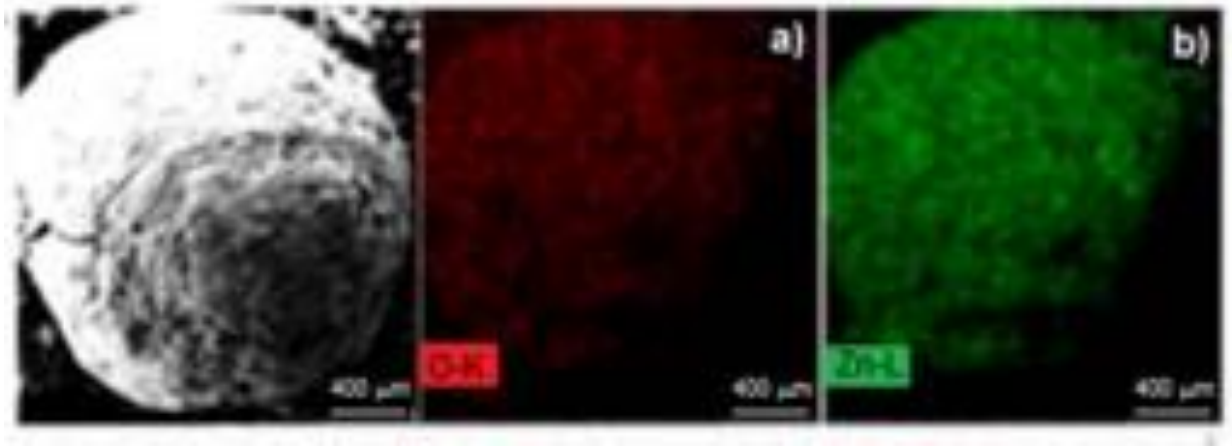
after

EDS for ZnO sorbent **before and after** adsorption.

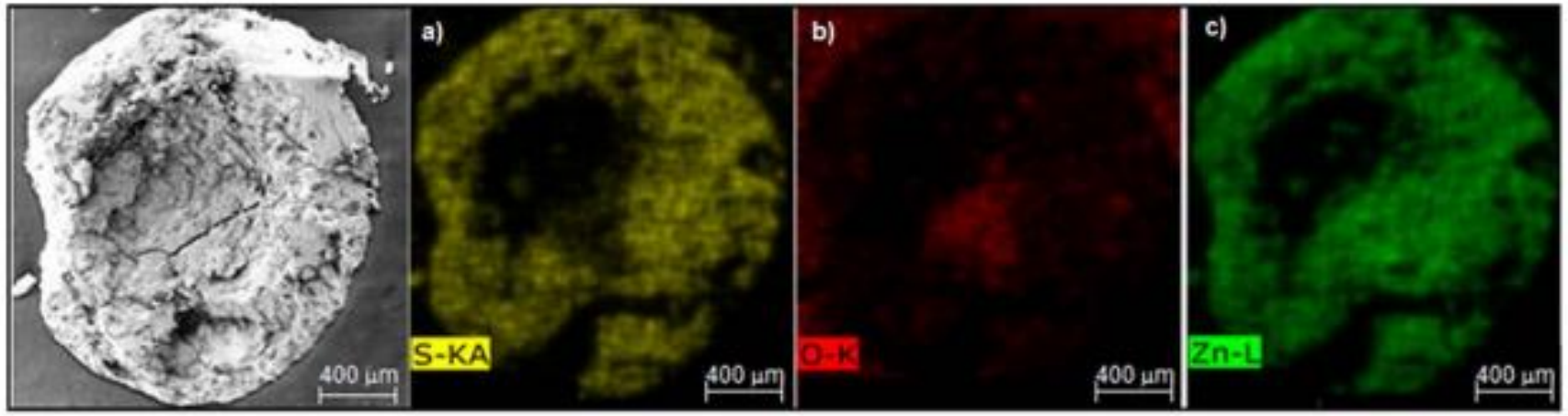




HTC: ZnO sorbents

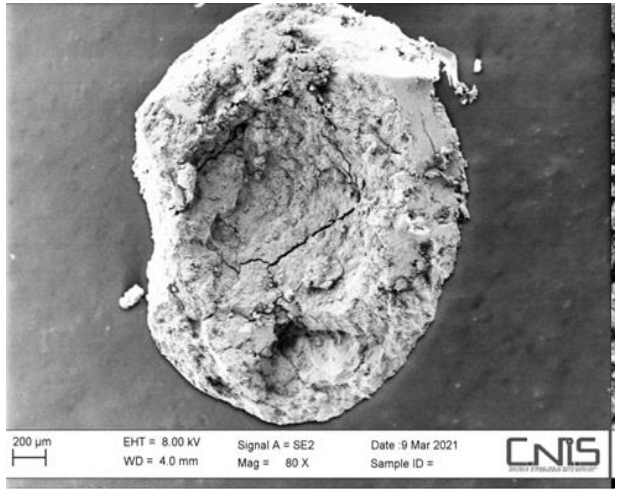


EDS analysis of sorbent **before** adsorption. The embedded map includes:
(a) oxygen
(b) zinc



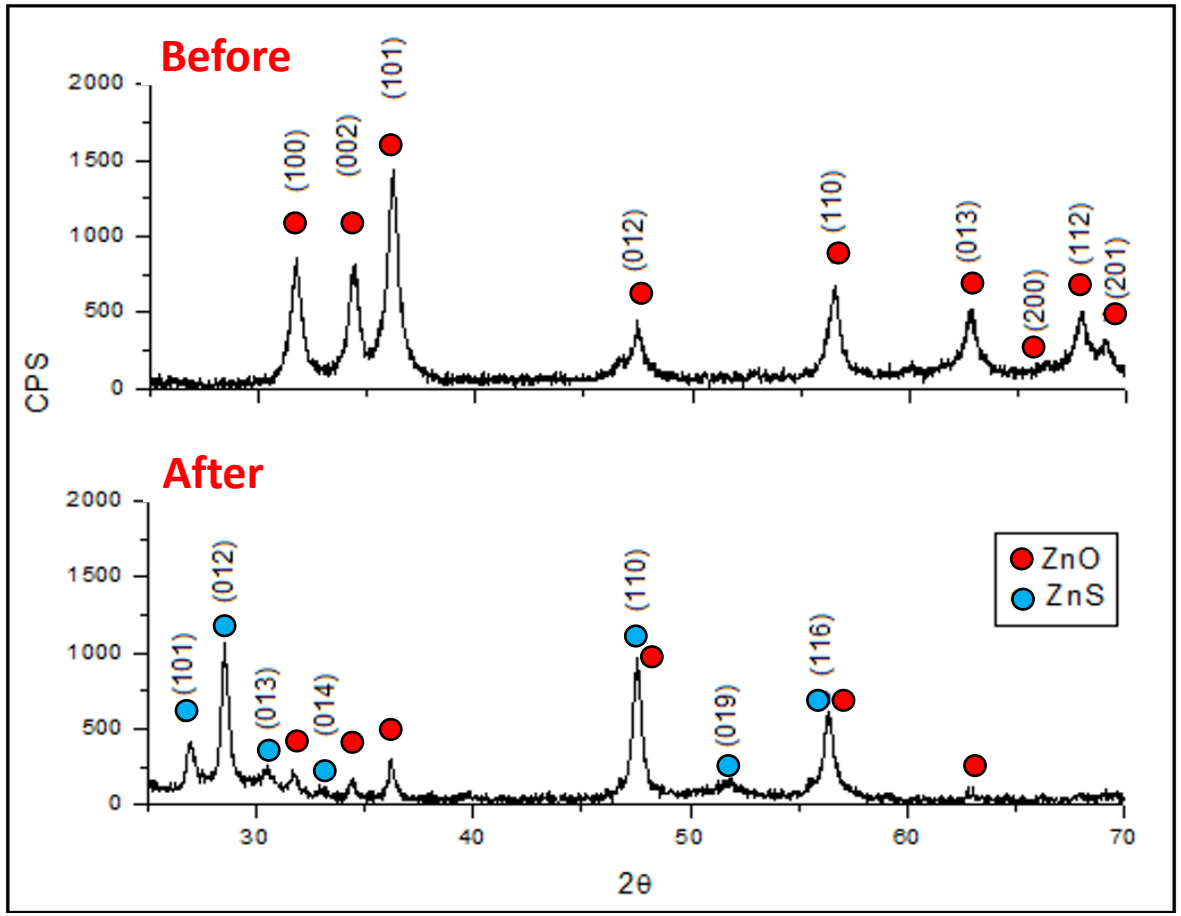
EDS analysis of the inner part of $ZnO_{(S)}$ sorbent **after** adsorption:
(a) sulphur
(b) oxygen
(c) zinc.

HTC: ZnO sorbents



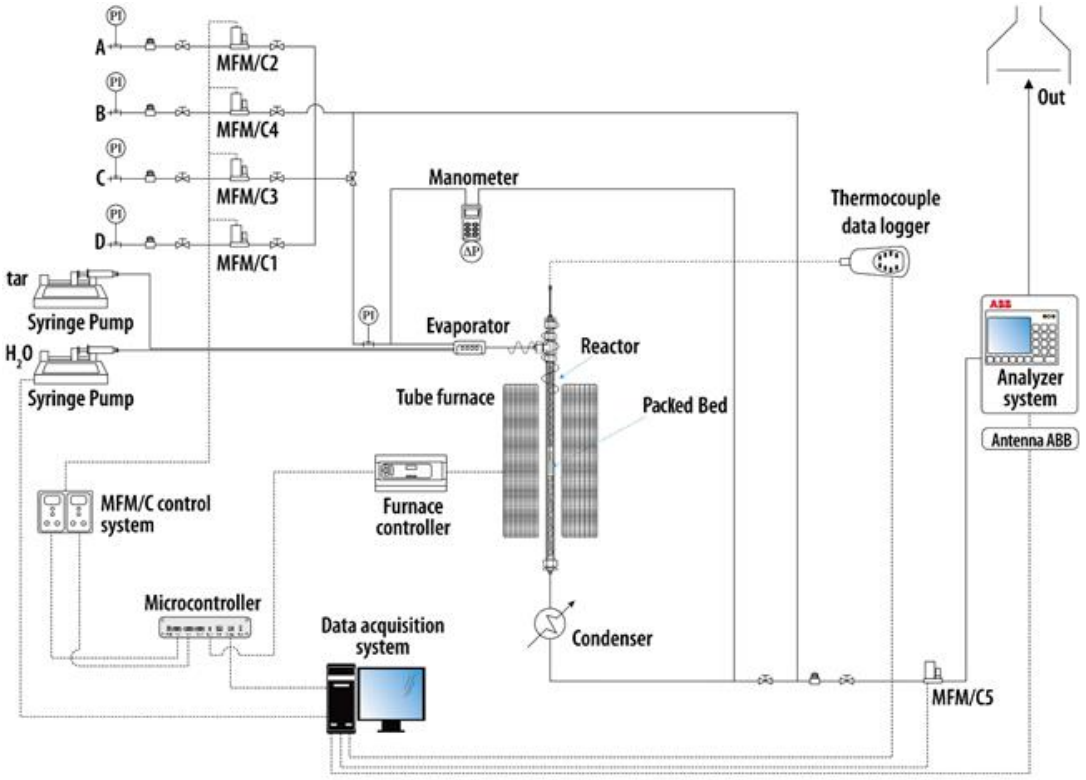
ZnO sample	BET ($m^2\ g^{-1}$)
Before	43
After	31

Porosity decrease



Hydrogen sulfide reacts with zinc oxide

HTC: Ni-based catalysts



Setup for Ni-based catalysts testing at University of Aquila

- Mixture of toluene/naphthalene (3.7:1) = synthetic tar

(S. Rapagnà, 2010), (E. Savuto, 2019), (M. Di Marcello, 2014).

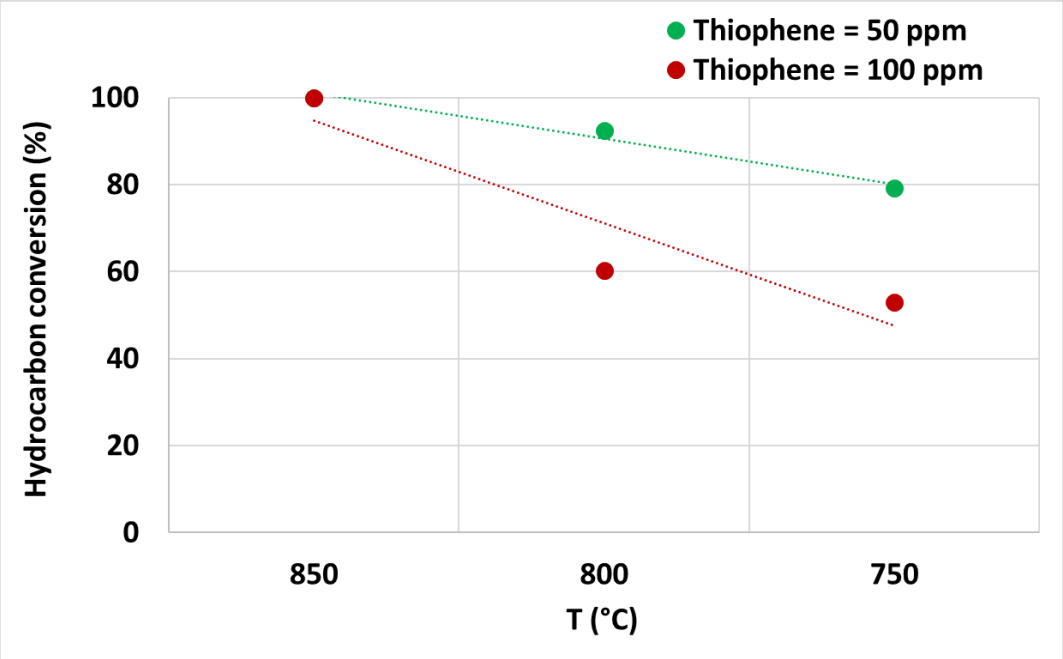
- Thiophene was added into the mixture as a sulphur source.

Experimental conditions of a simulated solution containing equivalent H_2S.

Condition	**Experimental levels**					
Pressure [atm]	1					
GHVS [h^{-1}]	4500					
Temperature [°C]	850	800	750	850	800	750
Thiophene [H_2S equiv, ppm]	50			100		

HTC: Ni-based catalysts

Inlet carbon conversion as a function of temperature for two different thiophene concentrations

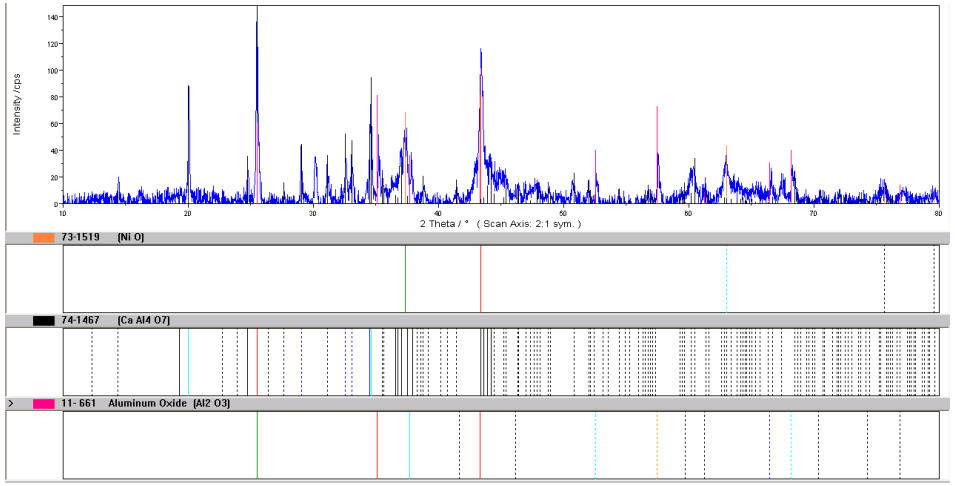


Ni-based catalysts

Sample of Ni-based catalysts	BET ($m^2\ g^{-1}$)
Before	15
After	11

HTC: Ni-based catalysts

Fresh catalyst

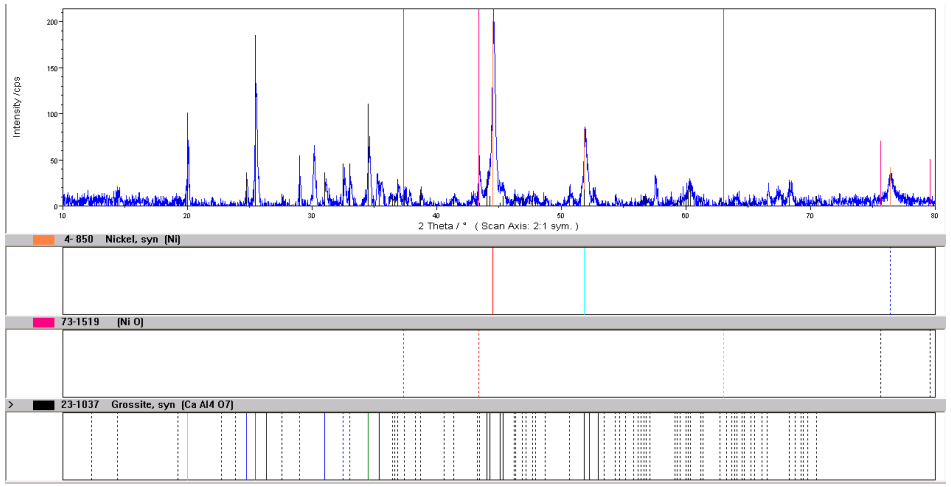


NiO

$CaAl_4O_7$

Al_2O_3

Spent catalyst

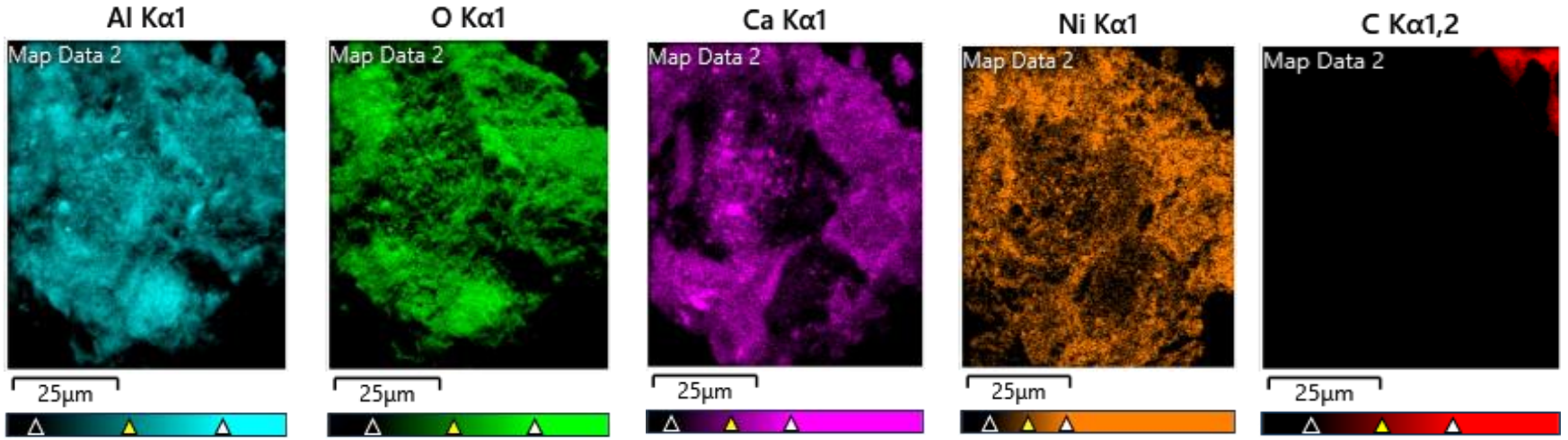


Ni

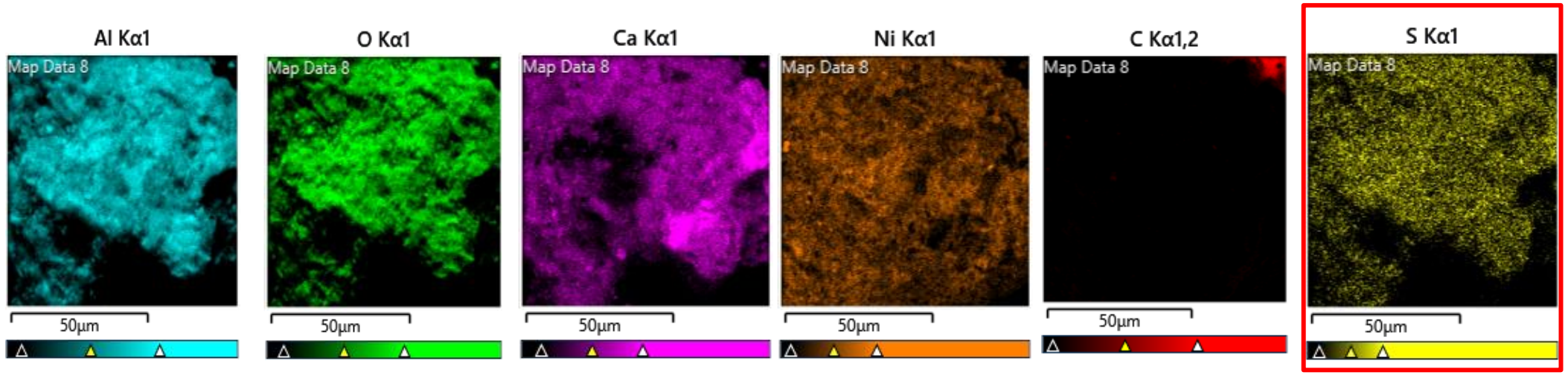
NiO

$CaAl_4O_7$

HTC: Ni-based catalysts

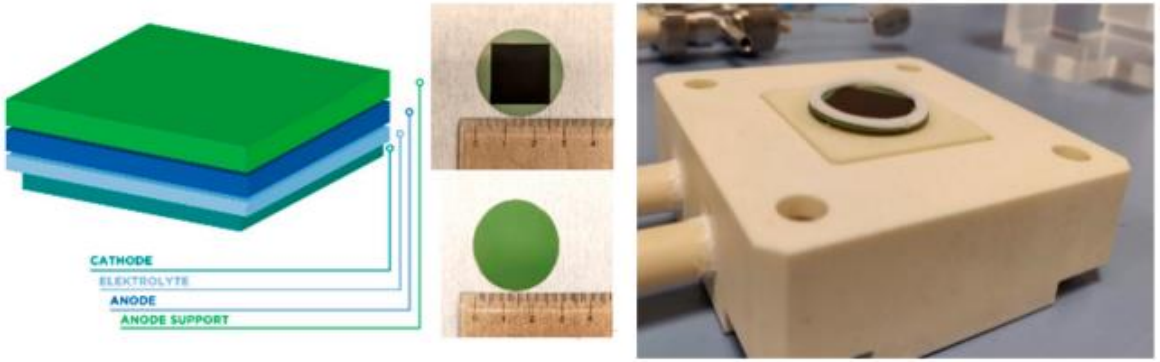


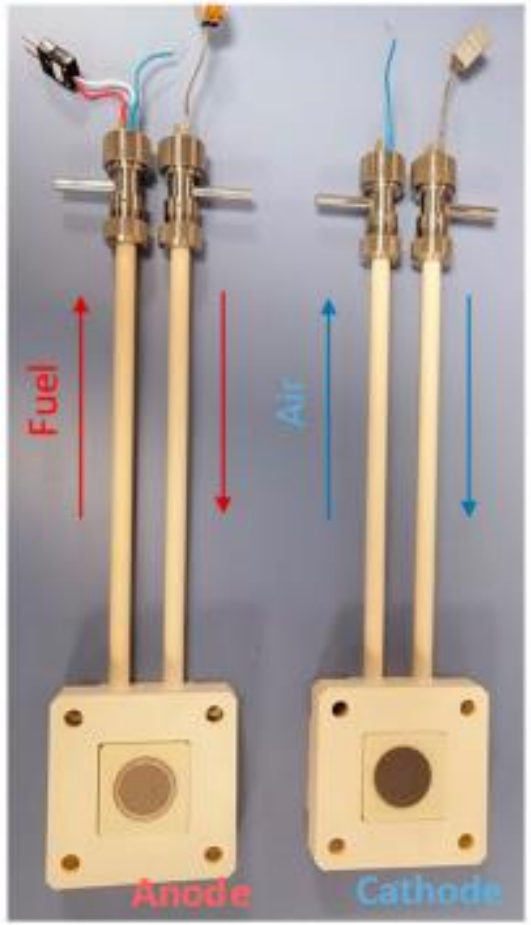
Fresh catalyst

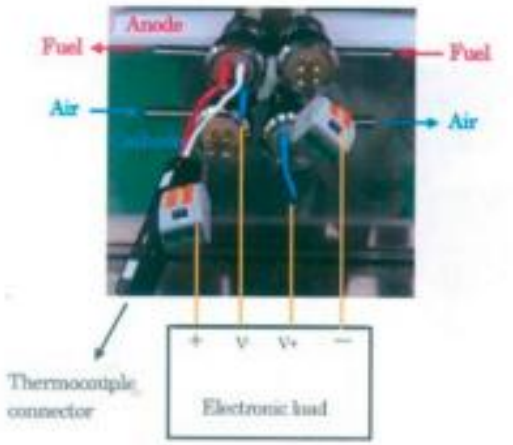


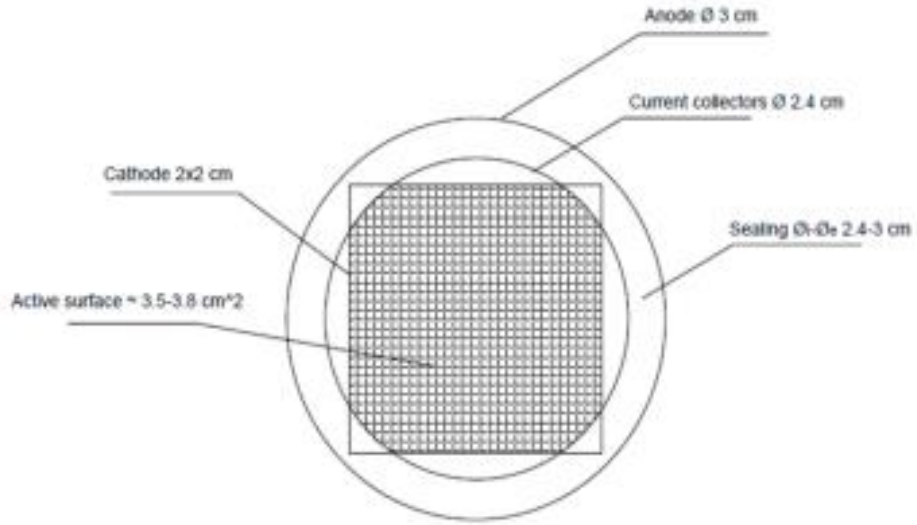
Spent catalyst

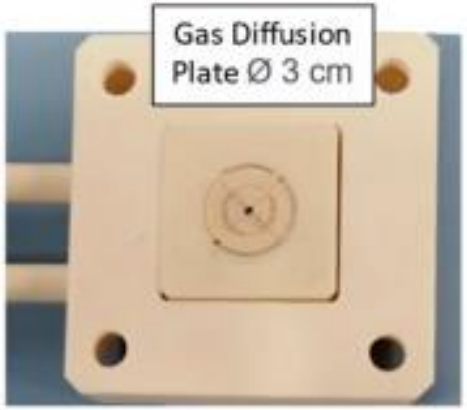
SOFC Test Bench





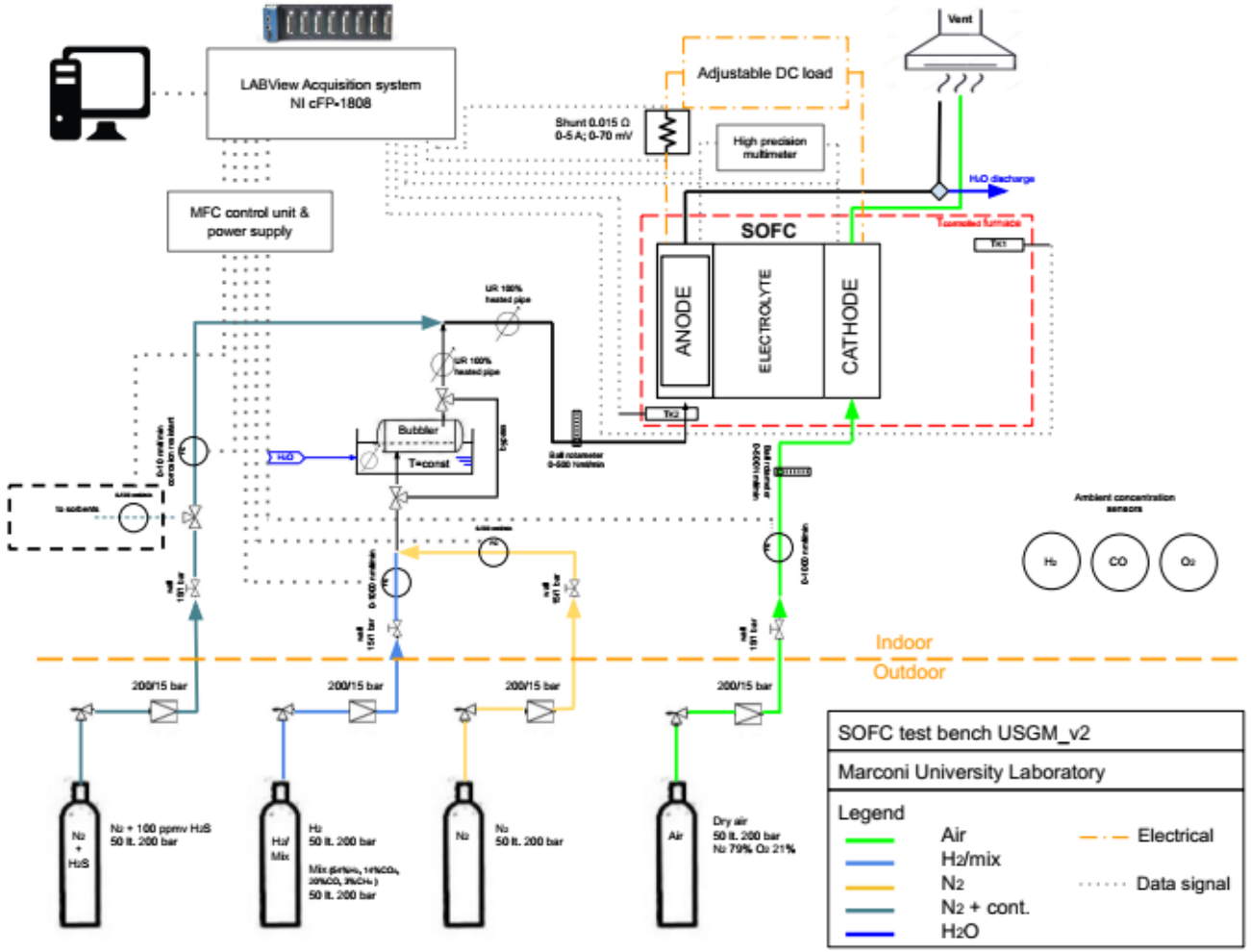


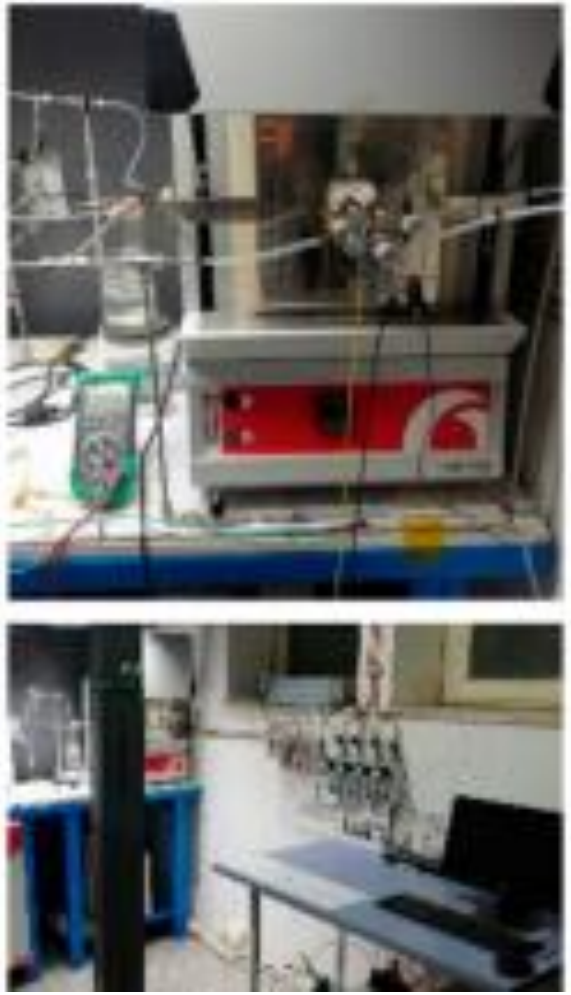




Setup for SOFC testing at USMG

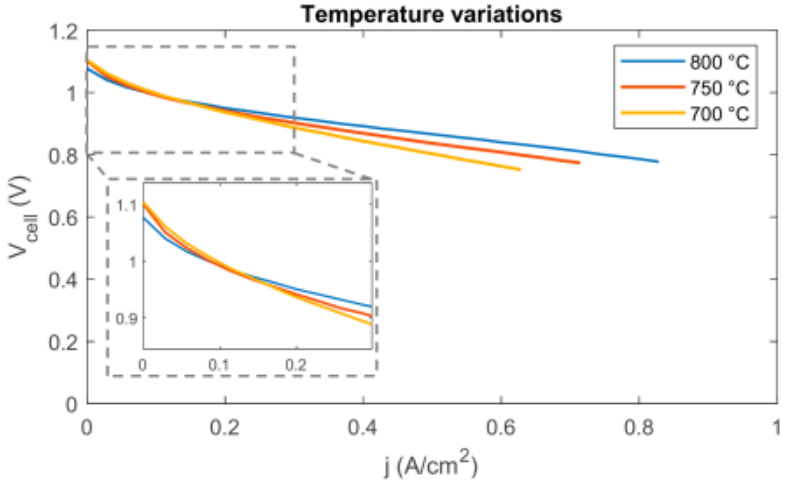
SOFC Test Bench: PID

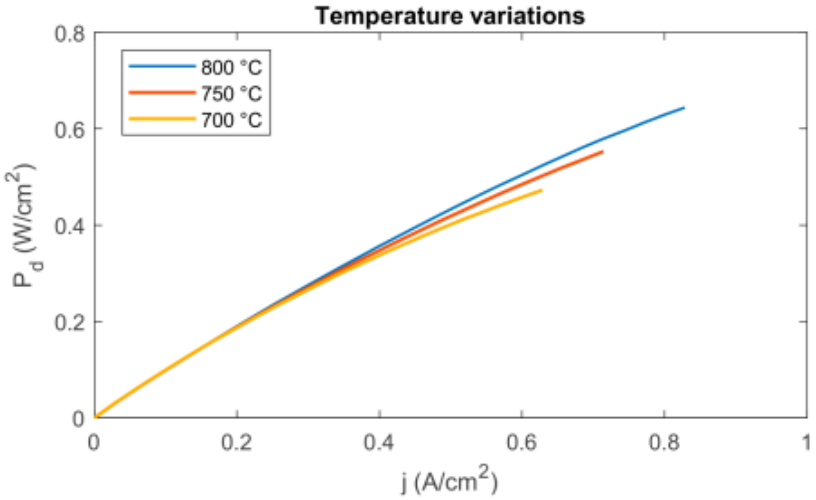




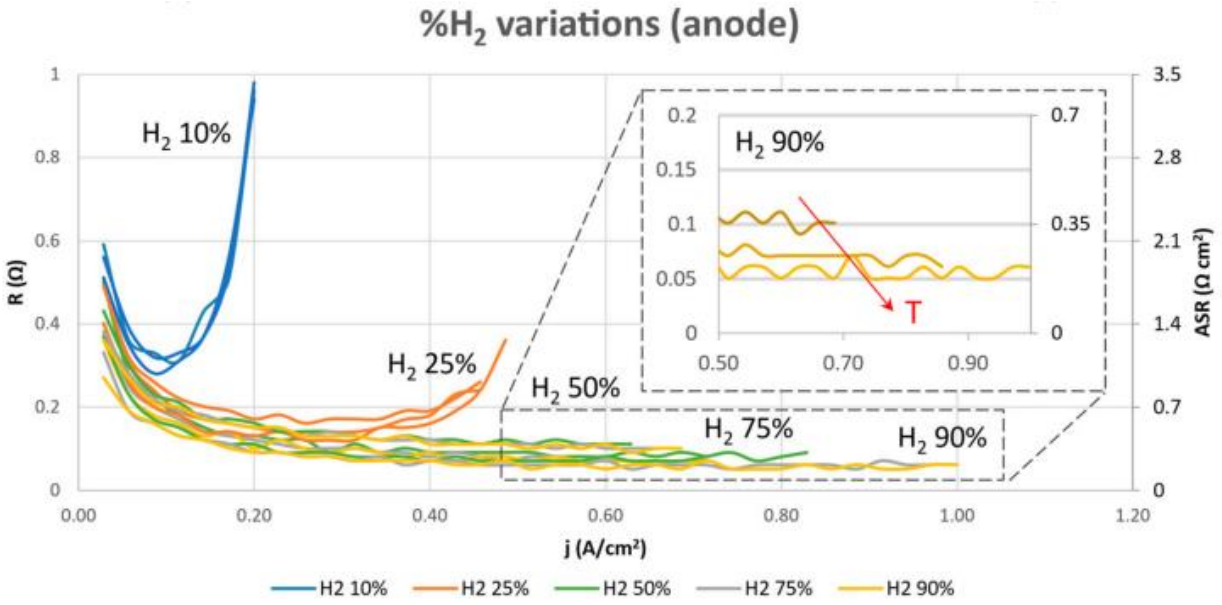
Laboratory at USGM

SOFC test





I vs V curve for temperature (H_2 50%vol; λ = 1.4)

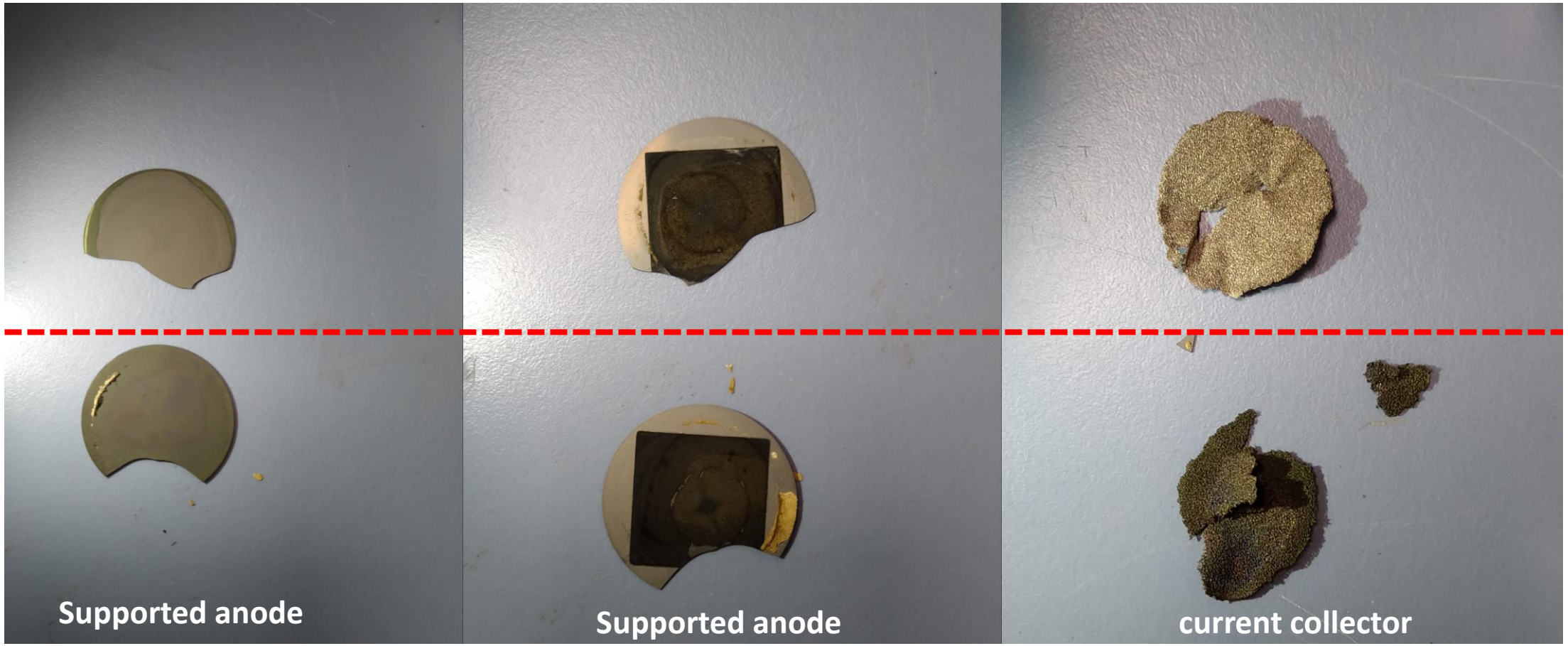


Resistance and Area Specific Resistance curve for H2%vol variations (T = 750 ◦C; λ = 1.4)

(L. del Zotto et al.)

(10.3390/en14082038)

SOFC test: Button cell analysis



Final remarks

- Physical and chemical characterization by XRF, XRD, CTS, SoX, SEM/EDS, BET are relevant techniques to evaluate the performance (initial correct composition and morphology, material stability, decay) of high temperature solid sorbents, catalysts, electrodes/membranes (SOFC).

- The suitable characterization of materials during process is a more and more required step to develop advanced conditioning stage, carbon capture utilization and storage (CCUS), PTG process, power production systems.

Thank you for your attention!

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