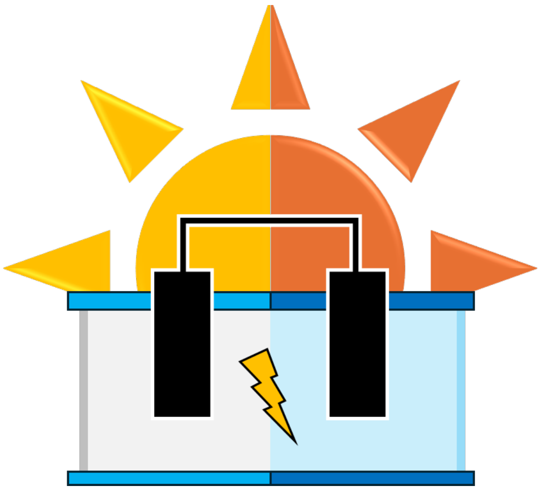
A Hybrid Reactor for Solar Carbon and Nitrogen Conversion Coupled to Wastewater Treatment



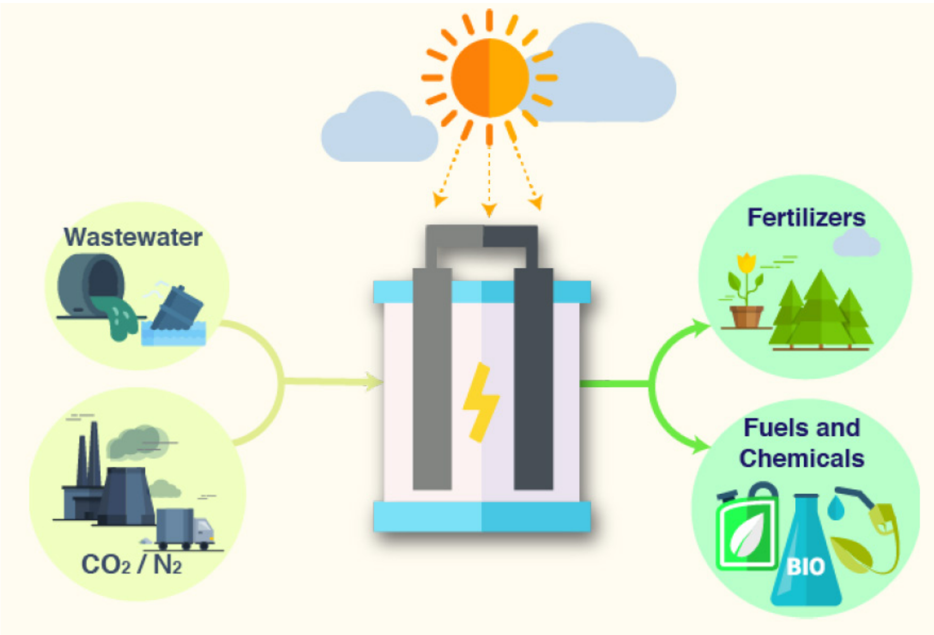
Available in Open Access
DOI: 10.5281/zenodo.13747785

This project has received funding from the European Union's Horizon Europe Research and Innovation Actions programme under grant agreement n° 101017928

INTRODUCTION

Greenhouse gases (GHG) such as carbon dioxide, methane and nitrous oxide absorb infraredradiation, trapping heat in the atmosphere. The increasing concentration of GHG in theatmosphere as a result of anthropogenic activities is the main driver of climate change.Carbon Capture and Utilization (CCU) approaches reduce the net carbon emissions ofotherwise carbon-intensive processes. The process of using sunlight for CCU, such as theone proposed in HySolChem, takes the name of Artificial Photosynthesis

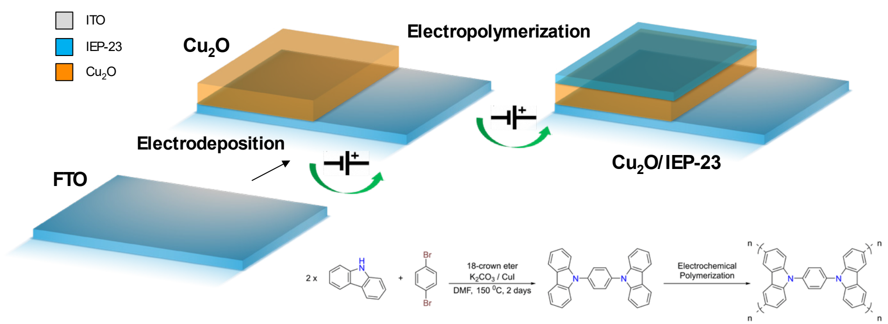
Our photoreactor drives the photo(electro)catalytic reduction of gaseous CO and N and usest heir oxidation potential to destroy microplastics and organic wastewater pollutants. The reduced CO and N are used to synthetize higher value chemical compounds, such as ethylene, methane, ammonia and urea. The process is circular and entirely carbon neutral, since the degradation of wastewater pollutants supplies more carbon andnitrogen which are used as oxidants in the reaction.



The HySolChem photoreactor is designed for municipal wastewater treatment plants, but it can be adapted for installation in the water treatment train of carbon-intensive industries (chemicals, refinery, cement, fertilizers) and energy producers.

Photocathodes

The photocatode is responsible for Carbon and Nitogen reduction (i.e. capture) and fixation in energy-rich compounds such as hydrocarbons, effectively driving the process of artificial photosynthesis



HySolChem is producing hybrid organic/inorganic photocathodes by **electropolymerisation** and **electrodeposition**: Different combination of *conjugated porous polymers* and inorganic, Cu-based semiconductors are deposited over transparent conductive substrates

Dr. Miguel Recedor
IMDEA Energia
miguel.tecedor@imdea.org

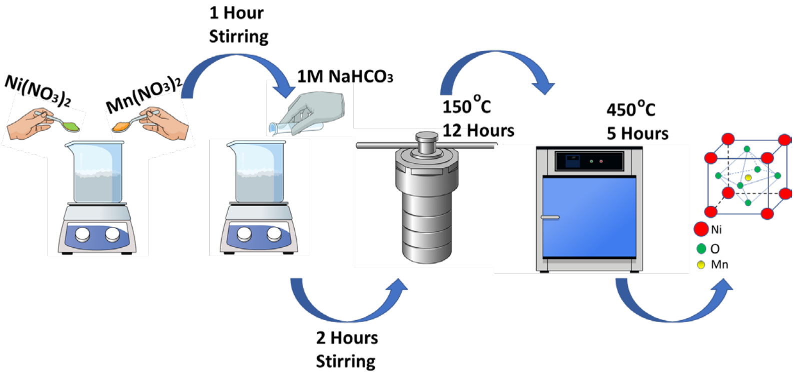
Non-critical!

Inexpensive!

Selective!

Dark anodes

The dark anode is responsible for the oxidation of pollutants in water. Electrochemical advanced oxidation processes are considered efficient and environmentally friendlier than other methods

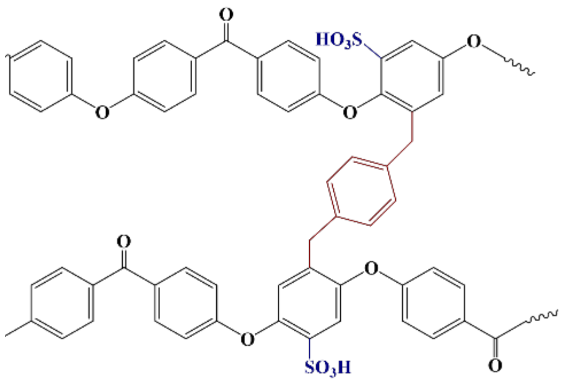


HySolChem is producing a Nickel - Manganese (Ni-Mn) binary oxide anode supported on Nickel Foam (NF). The anode, which has a final formulation NF/$NiMnO_3$, removed 90% of the phenol in 1 hour in contaminated water, and showed an 80% reduction of the Chemical Oxygen Demand in 5h, outperforming conventional anodes

Dr. Keyvan Mirehbar
IMDEA Energia
keyvan.mirehbar@imdea.org

Membranes

Traditional cation-exchange membranes use a perfluorinated membrane polymer. This polymer has a high environmental footprint and is a persistent pollutant. HySolChem makes membrane production more sustainable by using non-fluorinated materials.

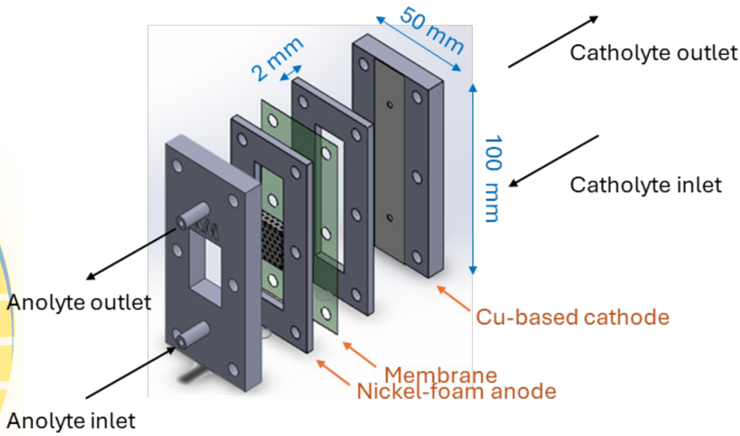


We designed a membrane polymer consisting of crosslinked sulfonated Polyetheretherketone (PEEK) membrane. We are able to synthesize the membrane outside of inert nitrogen atmosphere, and we are using non-hazardous organic green solvents from bio-feedstock

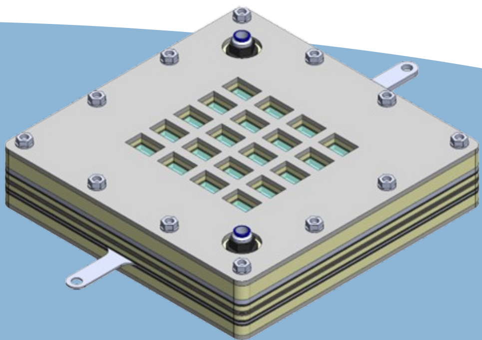
Stef Depuyft
KU Leuven
stef.depuydt@kuleuven.be

Reactor

Tto ensure uniform distribution of current and potential, lower internal resistance, and enhance the transport rate of electroactive species to the electrode surface.



In this configuration, an expanded graphite plate (Sigracell TF6) was strategically positioned in the internal blocks, holding the Ni foam anode centrally in the anolyte channel.

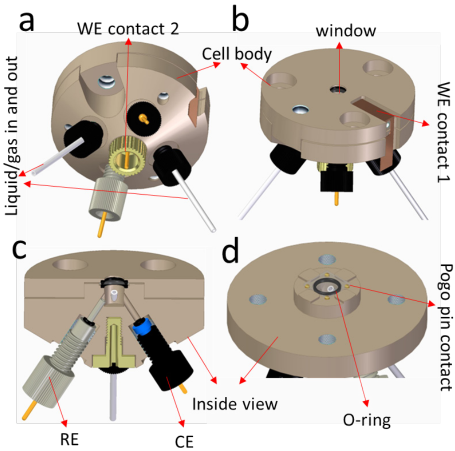


Final configuration of the HySolChem reactor

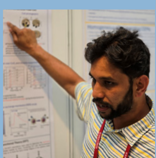
Dr. Esther Santos
APRIA Systems
esther.santos@apriasystems.es

Characterisation

An ad-hoc Operando / in-Situ Spectro-Electrochemical Flow Cell has been realised in order to test the reactor in XPS and NEXFSS studies at a synchrotron, and determine the reaction mechanism of Artificial Photosynthesis in the reactor



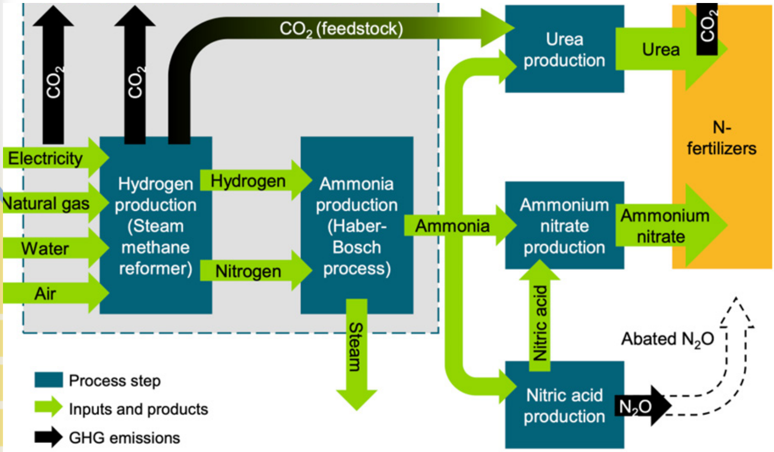
Transient Absorption Spectroscopy and Photoluminescence have been used to study the optical properties of the Cu-based photocathodes and to understand the charge dynamics. Together with Electrochemical Impedance Spectroscopy, we painted a picture of the physical processes taking place at different timescales



Dr. Santosh Kumar
Diamond Light Source
santosh.kumar@diamond.ac.uk

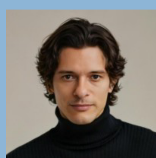
Exploitation

The Artificial Photosynthesis Reactor finds application in the industrial water treatment train of fuel and fertilizer producers. Both these processes generate CO_2 and contaminated water

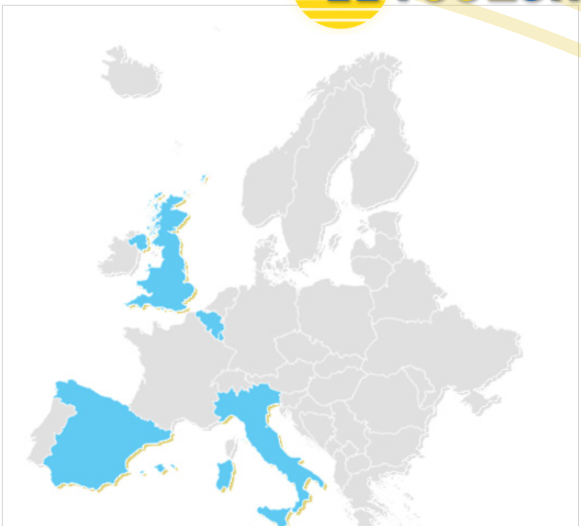


These are both inputs in the artificial photosynthesis reaction. As the reactor reduces the CO_2 and oxidizes the pollutant in water, it generates chemical compounds that can re-enter the fuel and fertilizer production

Dr. Fabio Ugolini
INNOVA Srl
f.ugolini@innova-eu.net



OUR TEAM



IMDEA ENERGIA
Project Coordinator

Dr. Víctor A. de la Peña O'Shea
Head of Photoactivated Processes Unit
victor.delapenya@imdea.org

Madrid, Spain
+34 917 37 11 20
info@hysolchem.eu

www.hysolchem.eu