EINDHOVEN UNIVERSITY OF TECHNOLOGY

# At the interface between materials and technology

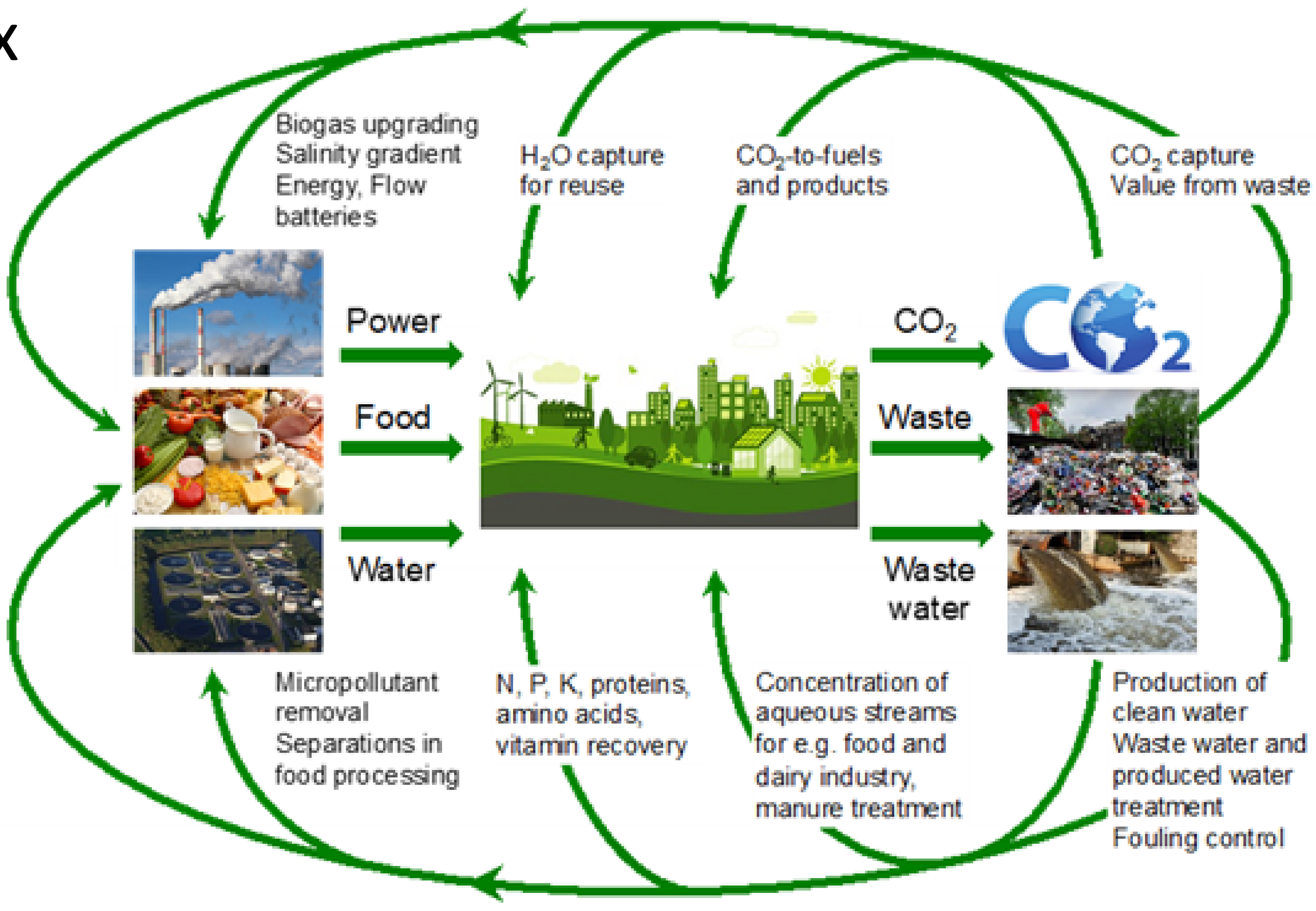
MM/P

## Introduction

Research in our group bridges polymer materials science and process technology. Consequently, assignments at the interface of both disciplines are available, but it is also possible to work on projects that have a strong focus on either polymer materials science or process technology. We try to shape assignments according to the specific wishes of the student, so feel free to discuss your ideas with us such that we can design an assignment fitting to your interests.

## Project summary

Typical assignment topics include, among others, the development, modification and preparation of new polymer membranes, membrane properties characterization (e.g. pore size and pore size distribution, charge, morphology, structure) and membrane performance studies. Typical application areas are in the water, energy and food industry (see figure). For aqueous applications we focus on the recovery of valuable components (e.g. minerals, proteins, amino acids) from waste streams, the purification of water for water reuse purposes and drinking water production. In terms of energy research is dedicated to the valorization of CO2 to produce fuels and chemicals, the upgrading of biogas or the purification of high pressure natural gas. Application studies include multicomponent mass transport using complex feed mixtures, investigation of transport using complex feed mixtures, investigation of interactions at the membrane-feed interface, structure-properties investigations and membrane performance (flux, retention) evaluation. Also the integration of membrane technology with other disciplines, e.g. conversion and separation or catalysis and separation for biorefinery applications or syngas production is part of our research portfolio.

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ELECTROCHEMICAL MATERIALS AND SYSTEMS

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# From Flooding to Flawless: Advancing Gas Diffusion Electrodes for Durable $CO_2$ Electrolyzers

**Senan F. Amireh, Antoni Forner-Cuenca**

## Introduction

The electrochemical reduction of $CO_2$ is a promising technology to produce sustainable chemicals and fuels through the utilization of captured $CO_2$. However, there are several challenges such as limited operational times and low current densities, which need to be overcome before commercialization.

## Project summary

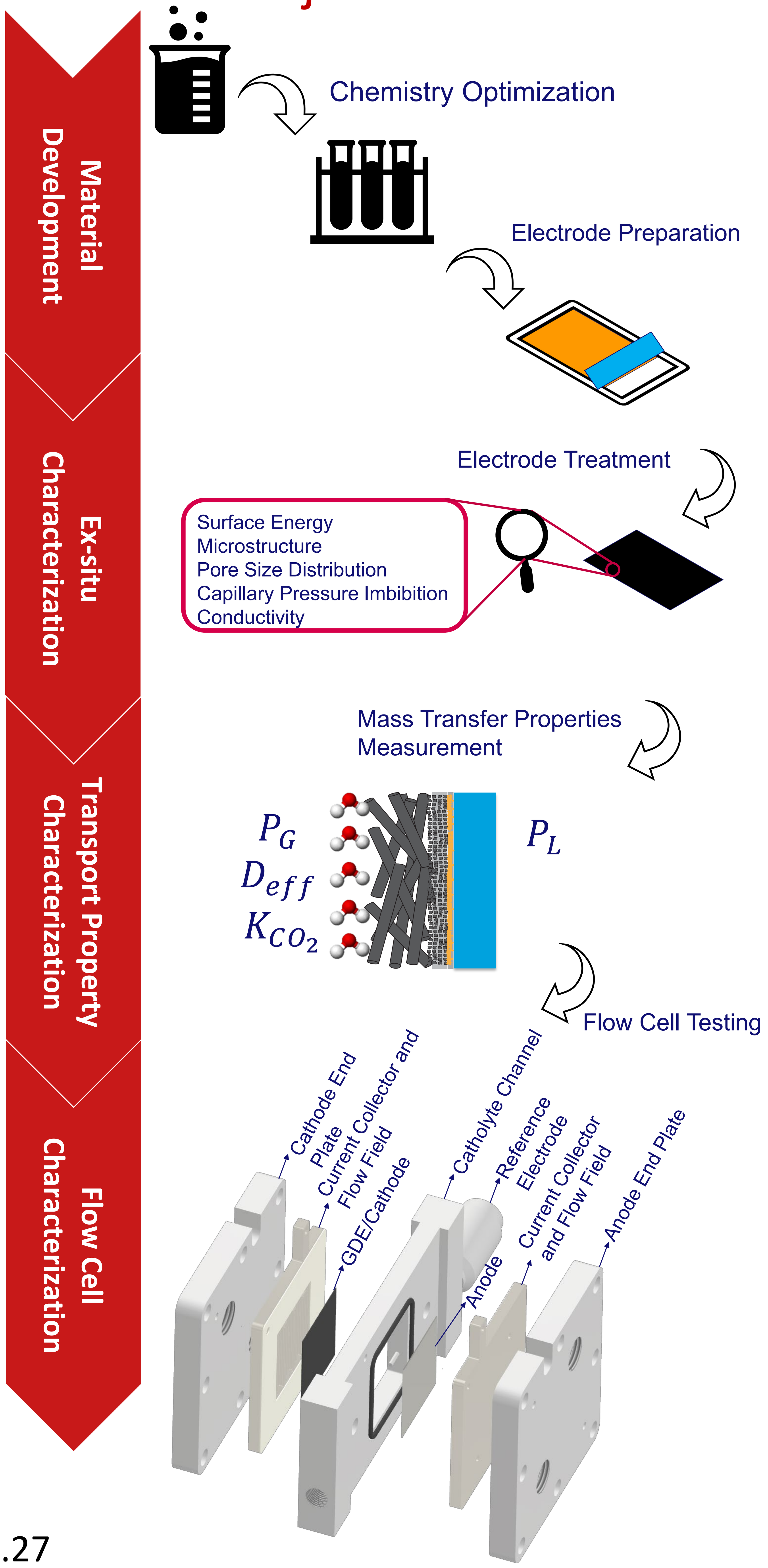
The gas diffusion electrode (GDE) is a key component which enables $CO_2$ electrolyzers to operate at higher current densities due to the porous structure that facilitates efficient gas diffusion to the catalytic surface. However, the current state-of-the art GDE materials have been repurposed from polymer electrolyte fuel cells and have not been tailored for the specific requirements of emerging $CO_2$ electrolysis cells. The current commercially available GDEs suffer from low durability due to flooding with operational times of less than 100 hours. Therefore, there is a need for tailored GDEs with controlled microstructure and hydrophobicity.

## Project goals

In this project, you will be challenged to:

1. Develop and optimize GDEs for $CO_2$ electrolyzers.
2. Model mass transport inside GDEs to predict optimal properties.

## Project Workflow

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Electrochemical Materials and Systems

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# From Big Data to Big Batteries: How Machine Learning Helps Redox Flow Batteries Keep the Charge Flowing

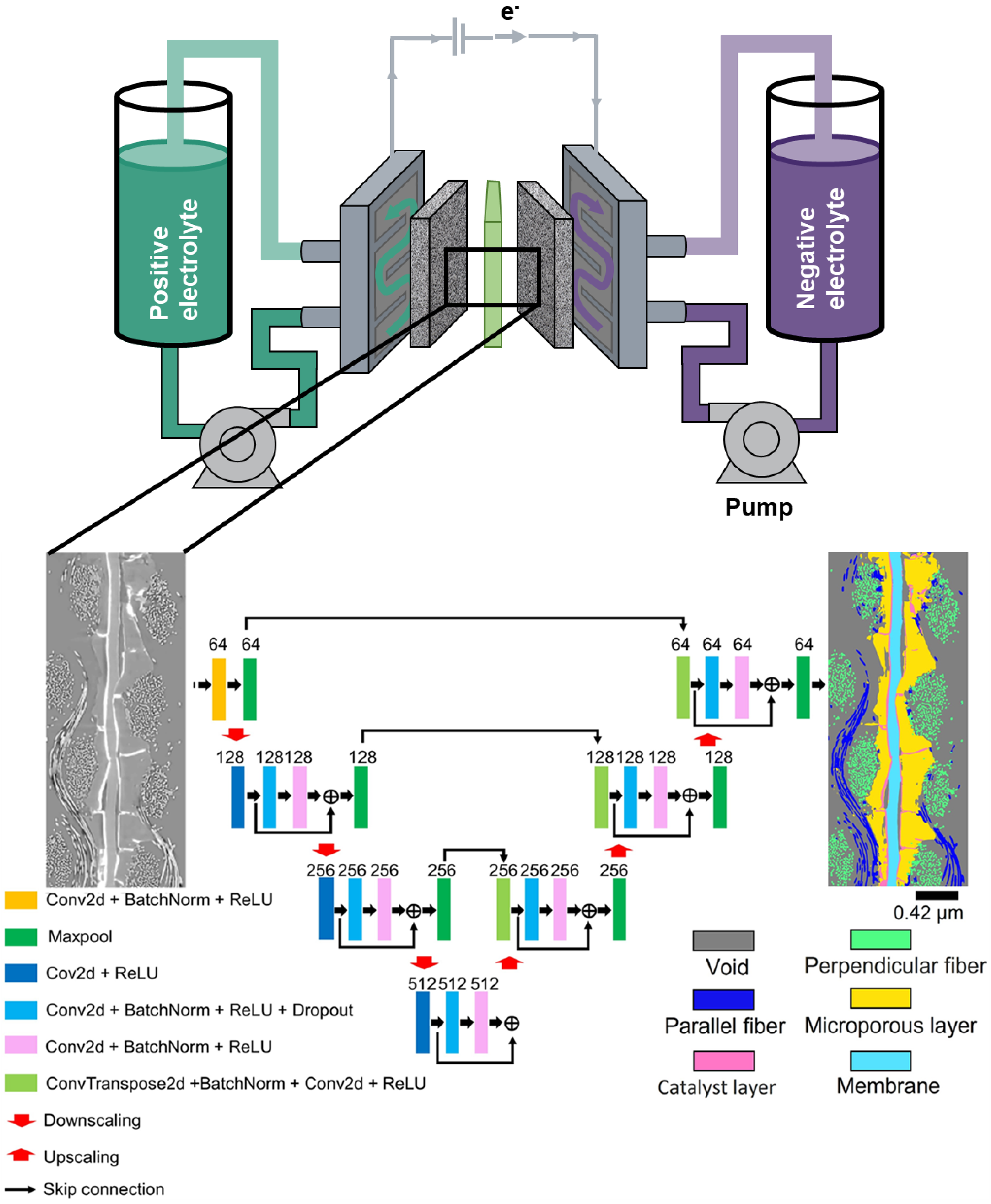
Mojtaba Barzegari, Antoni Forner-Cuenca

## Introduction

Machine learning (ML) and deep learning (DL) have emerged as valuable tools in the design and optimization of redox flow batteries (RFBs). RFBs are a promising technology for large-scale energy storage, but their performance can be influenced by a wide range of parameters, such as electrolyte composition, electrode material, and operating conditions. Developing ML models is useful for a wide range of applications in RFB design, including but not limited to materials design and discovery, accelerated multi-scale modeling, materials screening, electrode and cell manufacturing optimization, electrode architecture characterization, cell diagnosis and health predictions, etc.

## Project summary

In this project, the focus will be on the electrode processes and architecture to develop ML and DL models for segmentation and improvement of the resolution of CT images of the electrode. This can be further fed into generative models to create artificial yet realistic electrode geometries. The output will be used in computational models of RFBs to investigate the transport phenomena at the meso scale (pore level).




## Project goals

You will be in charge of building and training the segmentation and generative DL models for producing high-resolution electrode geometries. Some geometrical features of the generated architectures (e.g., diffusivity or permeability) can also be measured directly using ML methods.

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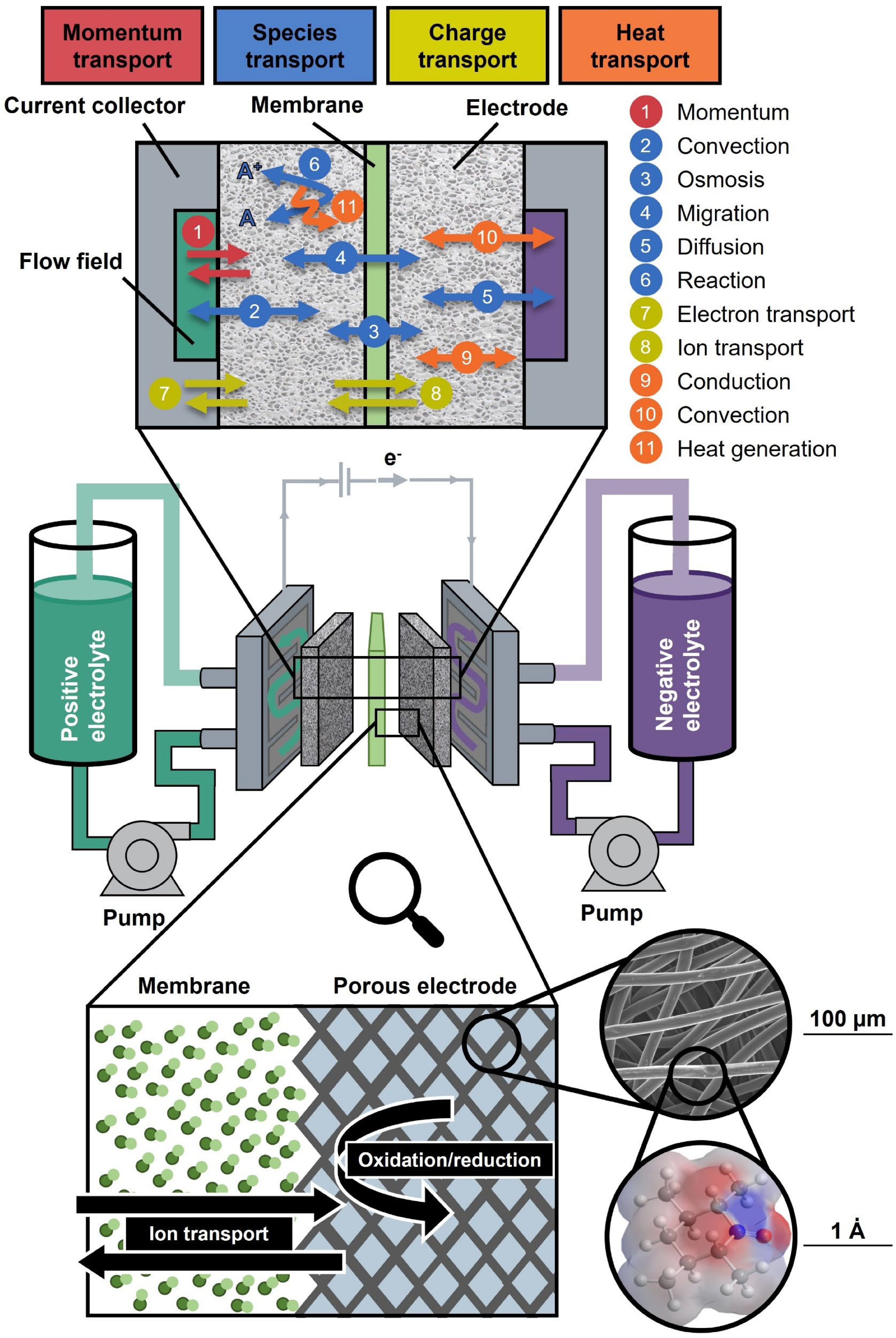
# Crunching Numbers to Keep Things Flowing: Computational Modeling of Redox Flow Batteries

Mojtaba Barzegari, Antoni Forner-Cuenca

## Introduction

Computational modeling and simulation have become increasingly important in the study and development of redox flow batteries (RFBs), a promising technology for large-scale energy storage. This approach enables simulation of RFB behavior under various conditions, reducing the need for costly and time-consuming experiments.




## Project summary

The electrochemical stack of RFBs consists of flow fields, porous electrodes, and membranes, where the active species undergo electrochemical reactions to charge/discharge the battery. Multi-scale computational models help us understand the interplay of phenomena occurring at several length and time scales, which can be further combined with optimization models (such as topology optimization) to accelerate the optimal design of RFBs.

## Project goals

You will be developing models to evaluate the performance of various design aspects of RFBs or optimize their components, focusing on the porous electrodes. The studied physics, scale and methodology can be chosen based on your interests from a wide range of multi-scale phenomena depicted in the figure.

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ems ELECTROCHEMICAL MATERIALS AND SYSTEMS

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Designing Hybrid All-Iron Flow Batteries Using Suspension Electrodes

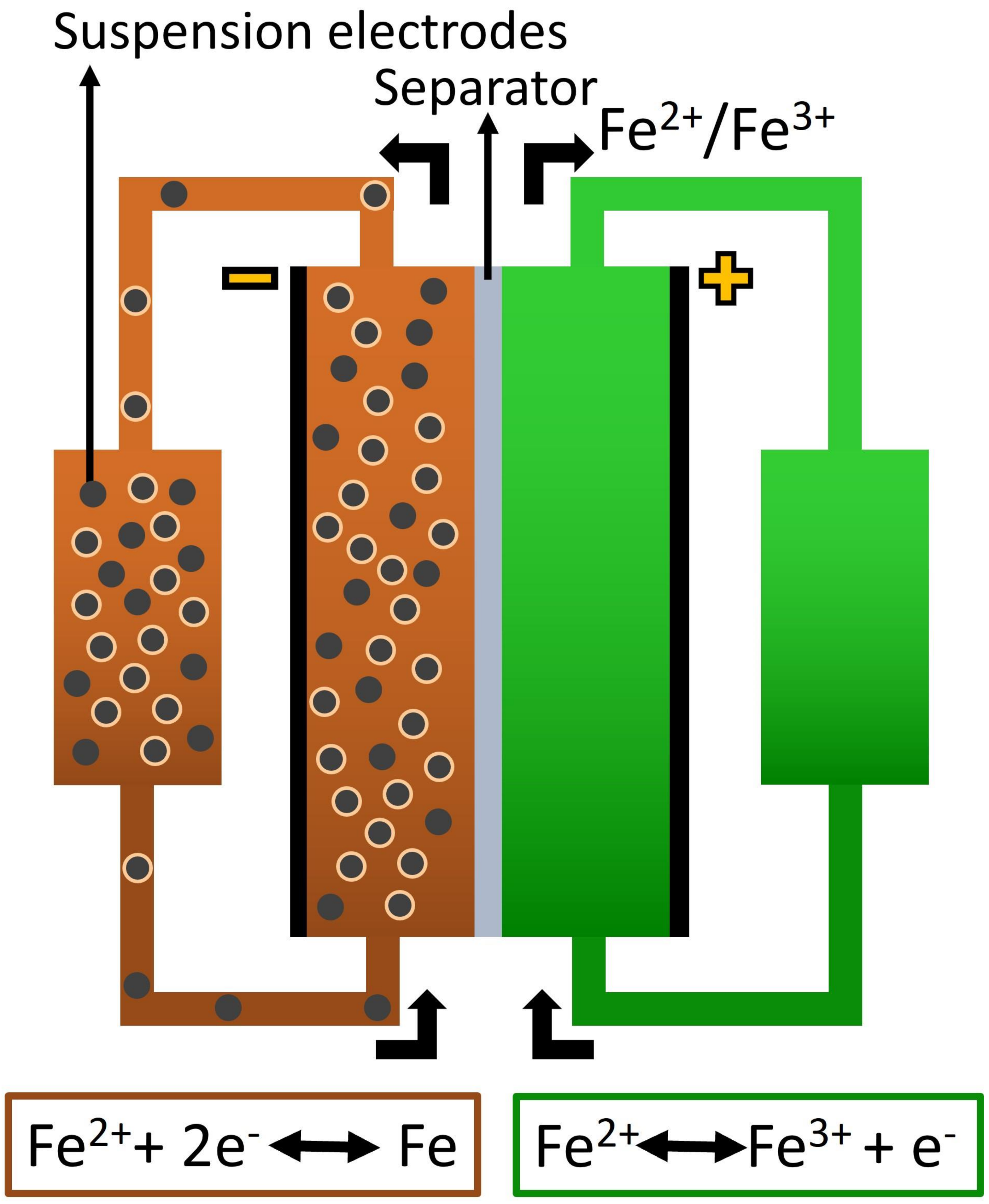
Ameya Bondre, Antoni Forner-Cuenca

## Introduction

Decarbonization of the energy sector can be achieved through renewable sources like solar and wind energy; however the intermittent nature of renewables causes grid instability. This issue can be tackled by developing long duration energy storage devices. Redox flow batteries are a promising energy storage technology as they decouple the energy and power needs of the grid. Currently commercial flow battery technologies utilize expensive active materials like vanadium, resulting in high energy storage costs.

## Project summary

Aqueous All Iron Redox Flow Batteries (AIRFBs) are considered a cost-effective option due to the large abundance of iron. However, the iron plating reaction at the negative electrode limits battery capacity. Hybrid reactor architectures could enable decoupling the energy and power capacity for AIRFBs. In this project we aim to employ suspension electrodes, consisting of conductive particles like carbon, which are recirculated through the electrochemical cell along with the electrolyte. During cell operation, iron plates onto these particles, thereby enabling the storage of active species outside the cell. Further, additives may be introduced to this electrolyte to improve charge transfer through these suspension electrodes.




## Project goals

In this project you will :

- ❖ Evaluate battery performance using polarization, stability tests and impedance spectroscopy.
- ❖ Analyze the effect of rheological properties of suspension particles.
- ❖ Study interactions between suspension electrodes, electrolyte and additives.

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CHEMICAL ENGINEERING AND CHEMISTRY

Membrane Materials and Processes

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Development of bipolar membranes for electrochemical applications

**Nadia Boulif, Zandrie Borneman and Kitty Nijmeijer**

## Introduction

Bipolar membranes (BPMs) are gaining increasing attention for their application in various electrochemical devices such as electrodialysis and electrolysis. A BPM consists of an anion exchange (AEL) and a cation exchange layer (CEL) that are laminated together, with a catalyst layer in between. This allows BPMs to act as reactors by splitting water into protons and hydroxide ions under reverse bias (**Figure 1**) or recombining the ions into water under forward bias.

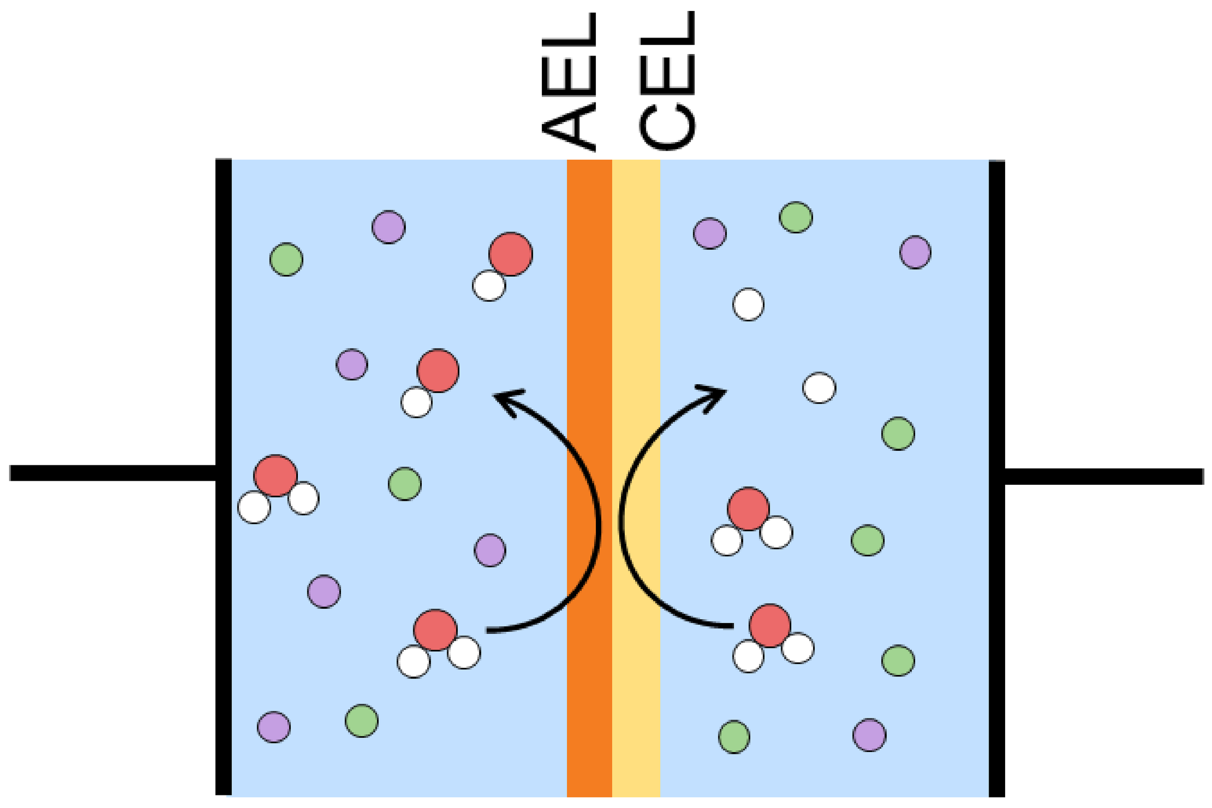


***Figure 1:*** *BPM under reverse bias (water splitting into $H^+$ and $OH^-$ ions).*

## Project summary

This project aims to understand how the catalyst layer at the BPM junction affects the BPM performance for electrochemical applications. To this end, bipolar membranes are produced by means of electrospinning and hot pressing (see **Figure 2**). Different BPMs with different catalyst layers assembled by layer-by-layer are made to investigate the effect of the catalyst layer on the membrane performance.

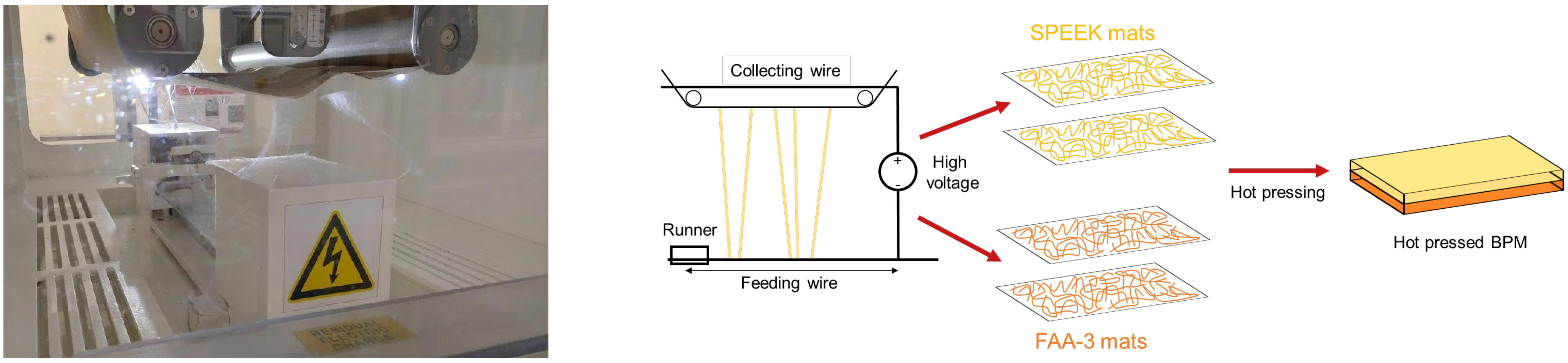


***Figure 2:*** *Preparation of the bipolar membranes with electrospinning. Left: picture of an electrospinning process. Right: schematic representation of the BPM fabrication steps.*

## Project goals

The main goal of this project is to understand how the catalyst layer in the BPM affects the BPM electrochemical performance and arrive at suggestions on how to improve the BPM performance based on the observed results.

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MMP Membrane Materials and Processes

CHEMICAL ENGINEERING AND CHEMISTRY

Membrane Materials and Processes

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Investigation of aqueous flow battery operating conditions on their efficiency

**Nadia Boulif, Zandrie Borneman and Kitty Nijmeijer**

## Introduction

The acid-base redox flow battery (ABFB) is an attractive energy storage solution as it relies on abundant, cheap and safe elements (sodium chloride and water). When excess renewable energy is produced, the electricity surplus is used to split water into a proton and hydroxide to store the energy in a pH gradient over the bipolar membrane (see **Figure 1**). When energy is needed, the acid and the base are neutralized to retrieve the stored energy. During this process, it is necessary to achieve high efficiencies to minimize the energy losses.

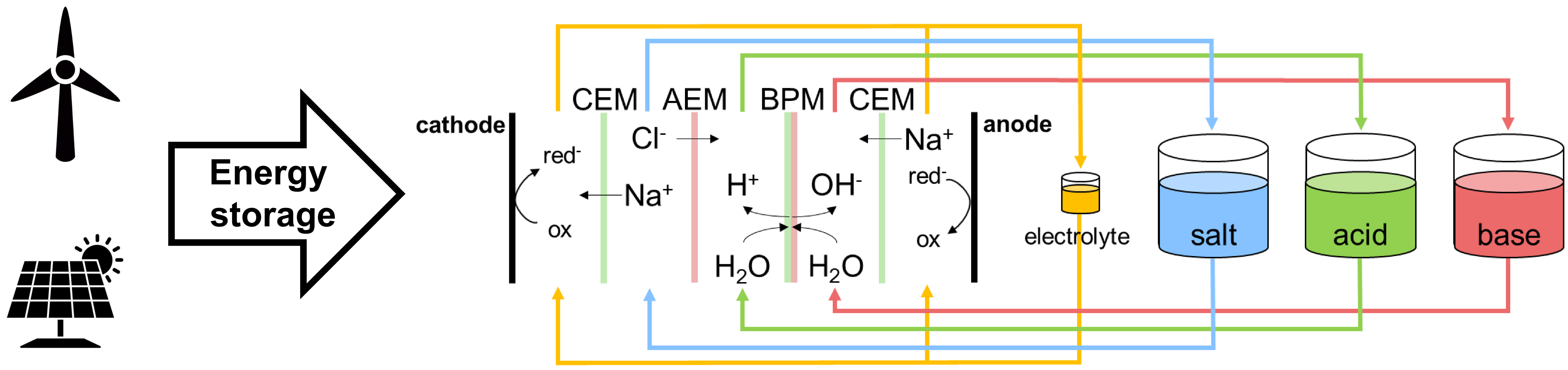


***Figure 1:*** *Charging of the ABFB, the arrows are reversed during the discharging process. Abbreviations used: CEM: cation exchange membrane, AEM: anion exchange membrane, BPM: bipolar membrane.*

## Project summary

The aim of this project is to measure the battery efficiency at different operating conditions (for example, different salt concentrations, states of charge, current densities, and types of salt). To this end, electrochemical techniques such as battery cycling and electrochemical impedance spectroscopy are used to determine how the operating conditions affect the battery performance. Ion chromatography is used to determine the ion concentration over time in the different compartments of the battery and understand the ionic transport taking place over the membranes in the battery.

## Project goals

Based on electrochemical and ion characterization techniques, the project goals are:

- Understand and explain why some operating conditions are better than others
- Arrive at suggestions and advice on what operating conditions are preferred and why

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Membrane Materials and Processes

Electrochemical Materials and Systems

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Scaling up electrode manufacturing with non-solvent induced phase separation

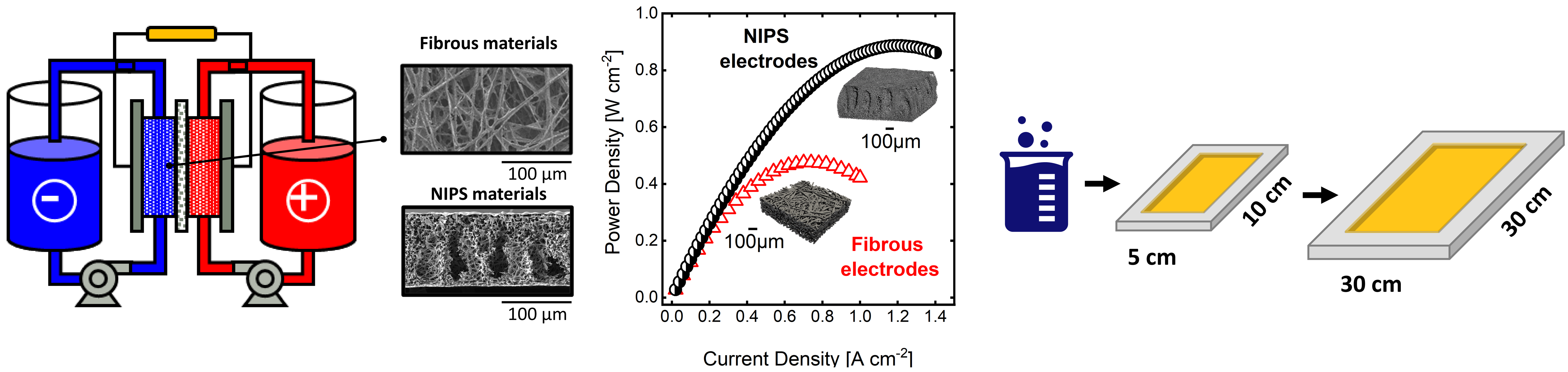
Simona Buzzi, Rémy R. Jacquemond, and Antoni Forner-Cuenca

## Introduction

Redox flow batteries (RFBs) are an emerging technological option for large-scale and multi-hour electrochemical energy storage due to their ability to decouple energy and power. Despite their intrinsic advantages, their current elevated costs hinder commercialization. To improve cost competitiveness, research efforts have focused on developing novel electrolyte chemistries and engineered reactor concepts. Optimizing the porous electrode microstructure and surface chemistry offers a promising pathway to increase the performance of RFBs.

## Project summary

Non-solvent induced phase separation (NIPS) is proposed as a versatile method to synthesize porous structures suitable for RFBs with unique properties, which are unattainable in current fibrous materials. By varying several parameters (e.g. polymers, solvent, temperature, etc.) a variety of different microstructures (e.g., macrovoids, isoporous or porosity gradient) can be achieved without involving complex steps. The combination of large macrovoids and high surface area is highly beneficial as it reduces convective transport and kinetic losses.




## Project goals

The goal of this research is to synthesize porous electrodes with NIPS and demonstrate the scalability of the method. A fundamental study on the phase separation phenomena will be carried out in order to understand the influence of different parameters on the phase-separation process. Finally, in-situ experiments in flow batteries will be performed to demonstrate the potential of the phase separated materials

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CHEMICAL ENGINEERING AND CHEMISTRY

Electrochemical materials and systems

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Designing Gas Diffusion Electrodes with Tailored Wettability for $CO_2$ Reduction Electrolyzers

Mert Can Erer and Antoni Forner-Cuenca

## Introduction

Rapid progress in the climate change necessitates the decarbonization of the chemical production industry. In this regard, electrochemical reduction of $CO_2$ is an effective system for carbon utilization and conversion to synthesize valuable chemicals such as ethanol, ethylene, etc. In this project, our aim is to enhance the stability and liquid product concentration of $CO_2$ reduction reaction ($CO_2$RR) electrolyzers, by developing novel gas diffusion electrodes (GDEs) with tailored wettability. To this goal, polymer chemistry and coating science will be employed to impart the desired functionalities.

## Project summary

The commercially available PTFE-coated gas diffusion layer (GDL) materials fail to resist the imbibition of alcohols with low surface tension values produced through $CO_2$RR. This results in catastrophic flooding, dramatically reducing the overall reactor stability. Hence, the project proposes the incorporation of nonfluorinated alcohol repellent coatings to GDLs.

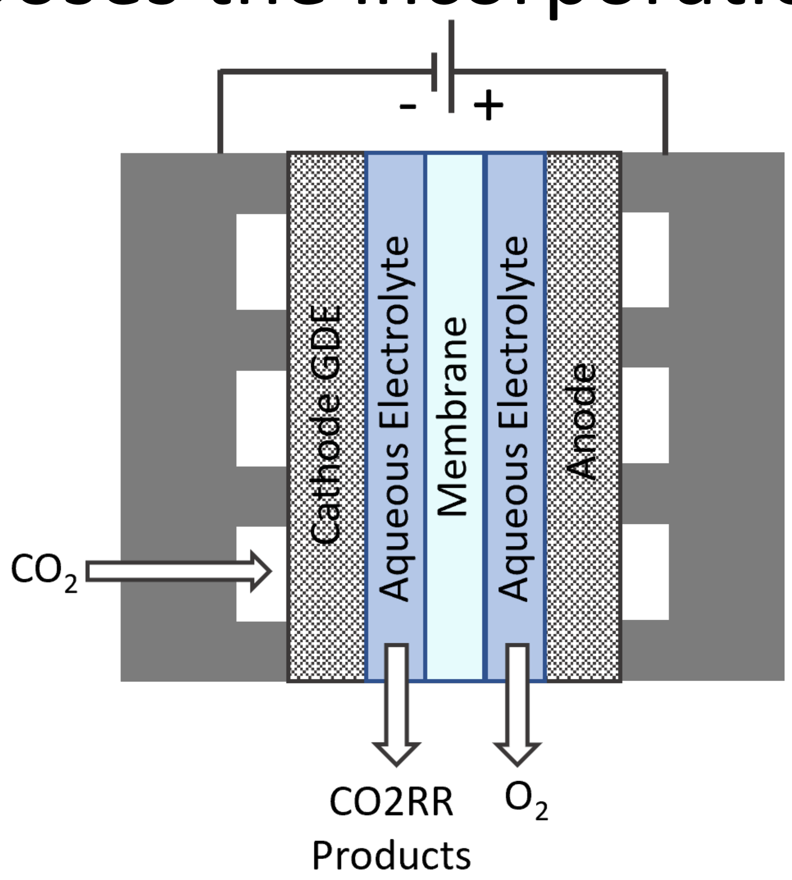


***Figure 1.*** *Schematic representation of a $CO_2$ electrolyzer*

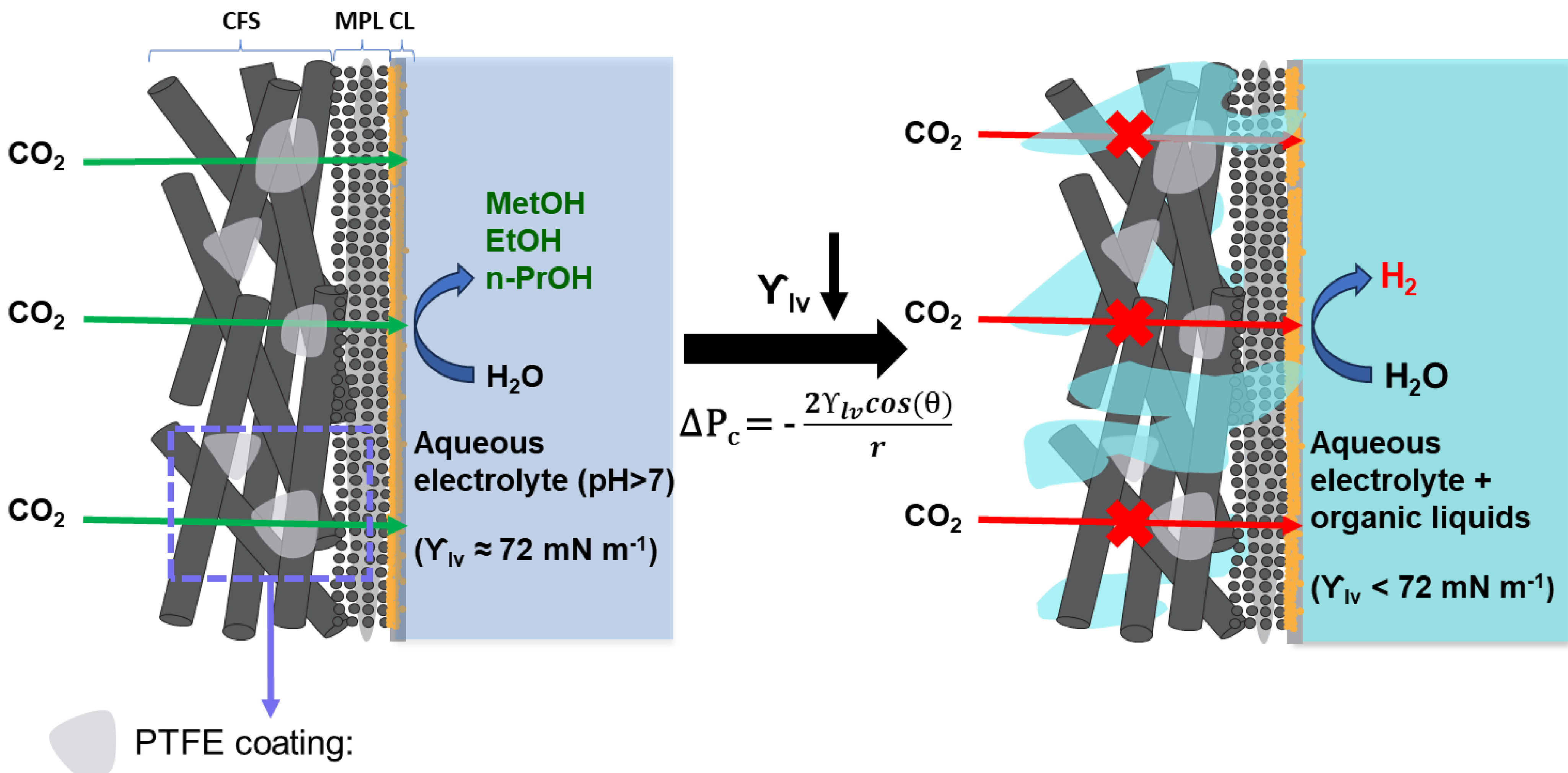


***Figure 2.*** *Illustration of flooding of a GDE upon alcohol production*

## Project goals

You will synthesize and coat non-fluorinated materials on flat conducting substrates (e.g. glassy carbon) and engineer the electrode topography to achieve alcohol contact angle values reaching 50°. Several internal and external wettability tests will be performed to assess liquid repellency of the modified GDLs. The structural and morphological analyses of the developed coatings will be performed via spectroscopy (e.g. XPS) and microscopy (e.g. SEM).

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ems

Membranes Materials and Processes
Electrochemical Materials and Systems

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Engineering electrodes for rechargeable iron-based flow batteries

Inma Gimenez-Garcia, Antoni Forner-Cuenca

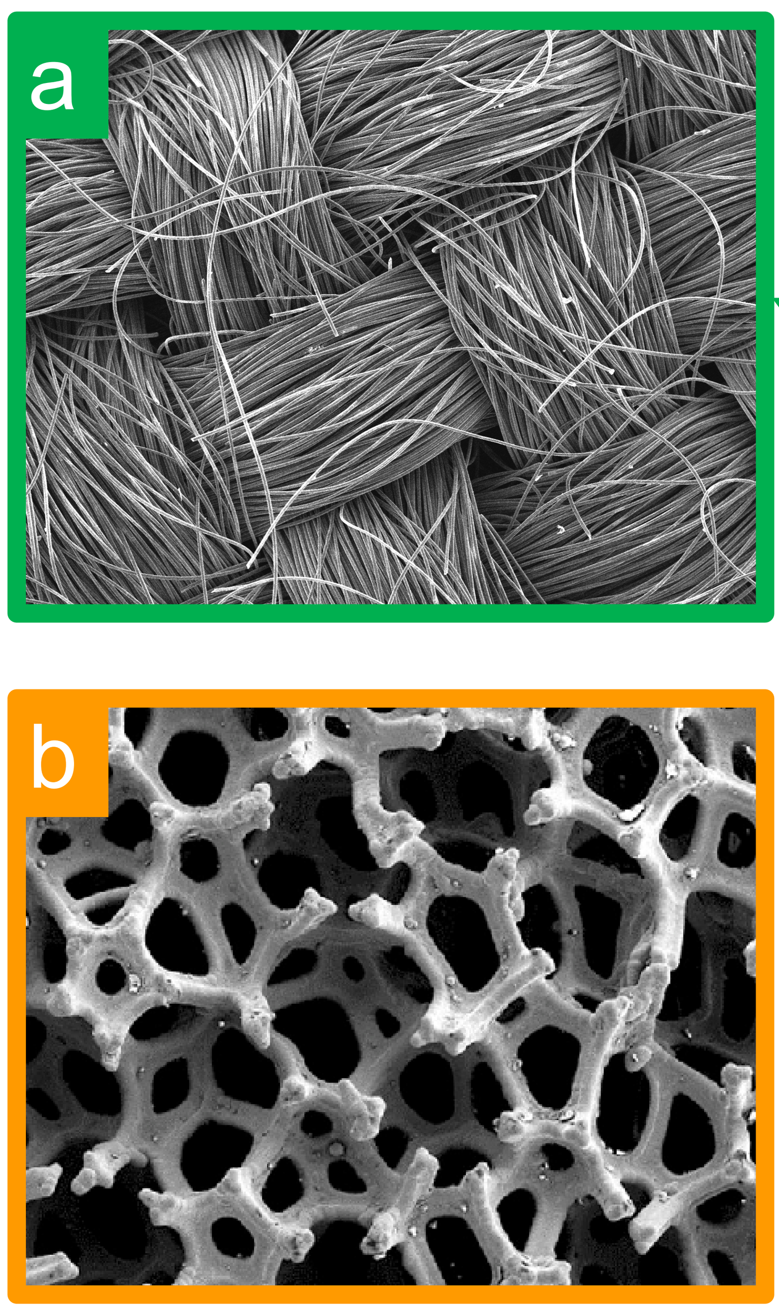
## Introduction

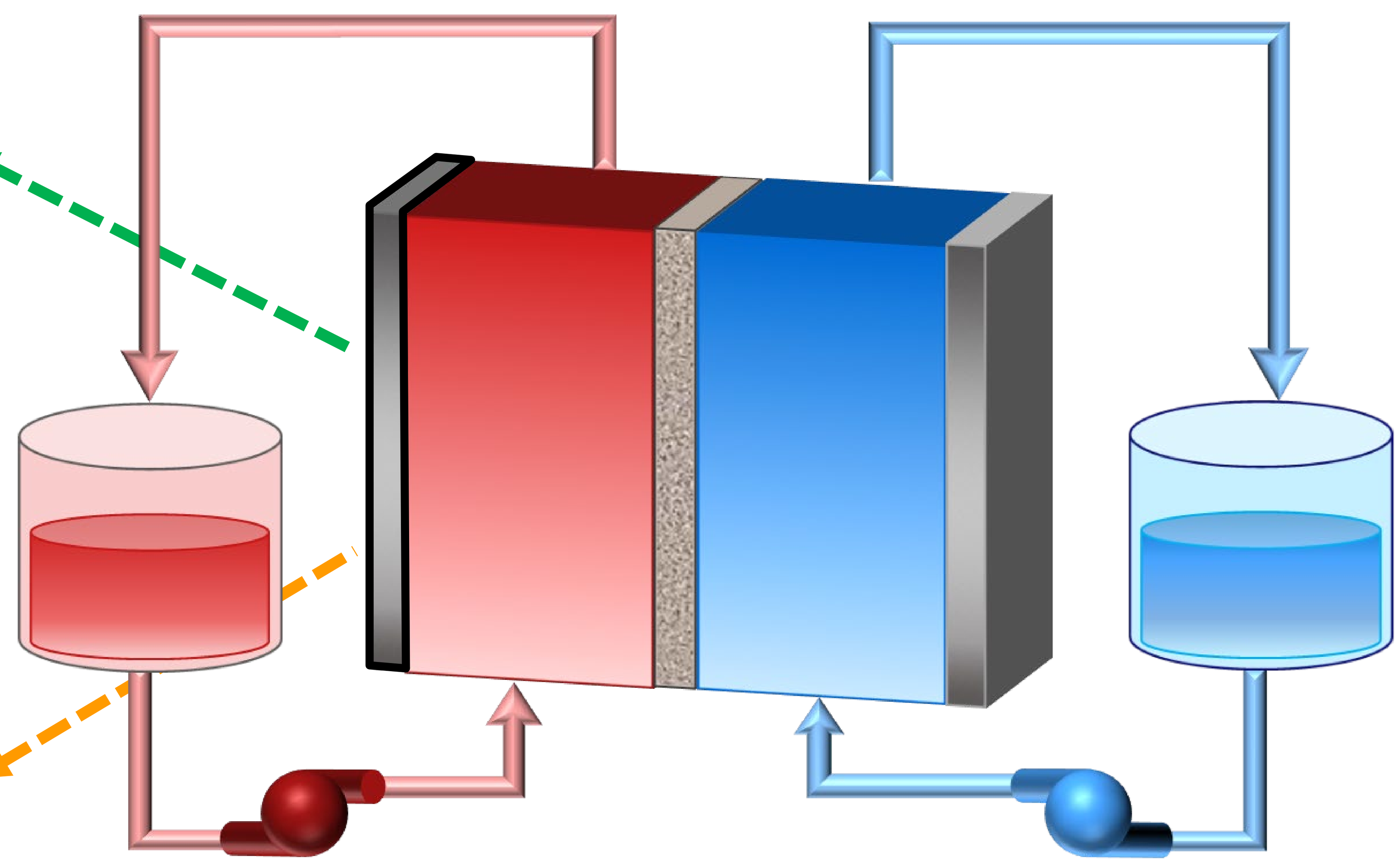
Exponential economic growth necessitates an effective transition to a renewable energy scheme, to achieve the stringent environmental targets. Advanced energy storage systems, such as Redox Flow Batteries (RFB) are promising candidates to overcome the main challenges, such as variability for both energy supply and demand at grid level.

## Project summary

The widespread deployment of RFBs is currently restricted by factors like material availability or costs. Aqueous All Iron flow batteries (AIRFB) can circumvent these issues by using environmentally friendly and abundant compounds, and common solvents.

However their capacity and durability are still largely limited due to side reactions, or sluggish kinetics in the negative half cell. Furthermore, most common electrodes for RFBs are carbon fiber based materials which do not readily support the solid ↔ ionic phase change



*Schematics of a RFB with conventional (a) carbon electrodes vs (b) metallic electrodes for phase change reactions*

## Project goals

In this project you will develop electrodes with advanced microstructure and surface functionalities to improve RFB performance from a hydrodynamics, mass transfer or reaction kinetics point of view . To achieve so you will

i) Manufacture advanced electrodes through different routes (non-solvent induced phase separation, multilayered self assembly of nano scale iron compounds)
ii) Physical and chemical characterization
iii) Electrochemical performance in all acid or mixed pH systems

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Membrane materials and processes

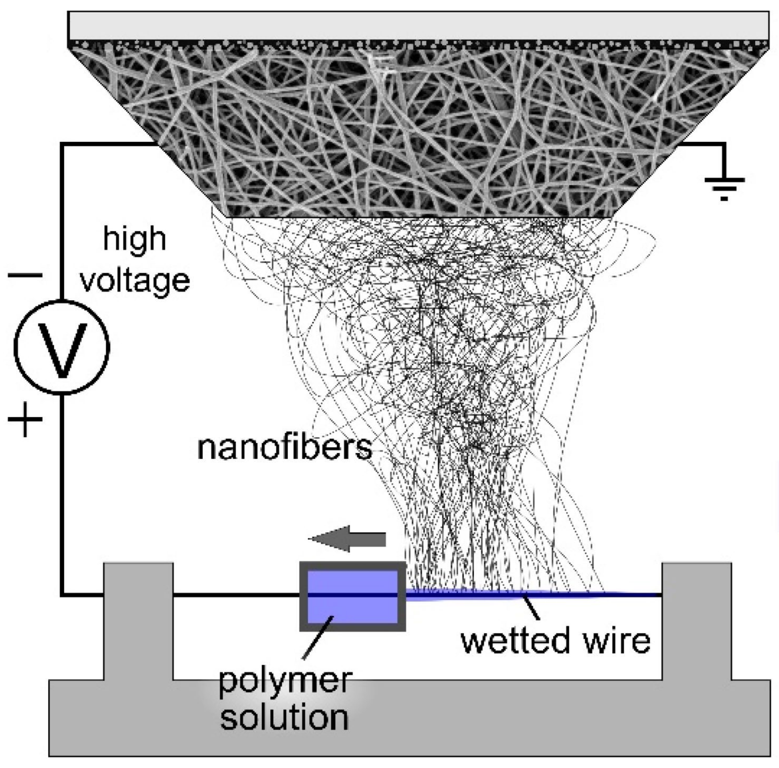
EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Investigation of Layer-by-Layer coating for forward osmosis membranes

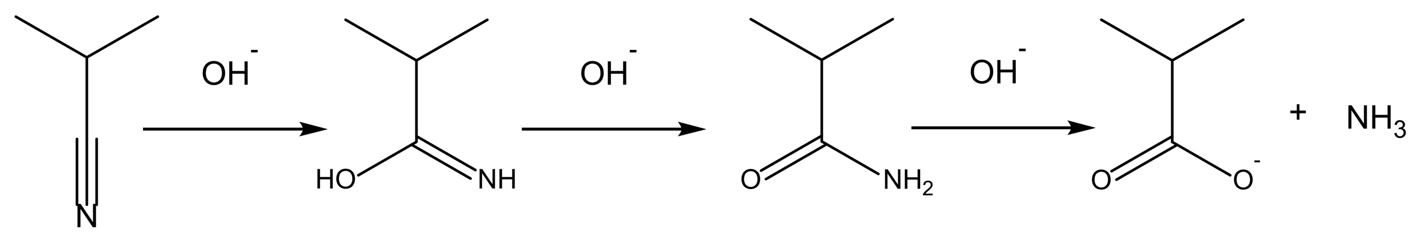
Aylin Kinik, Zandrie Borneman, Kitty Nijmeijer

## Project tasks

### 1. Membrane support production

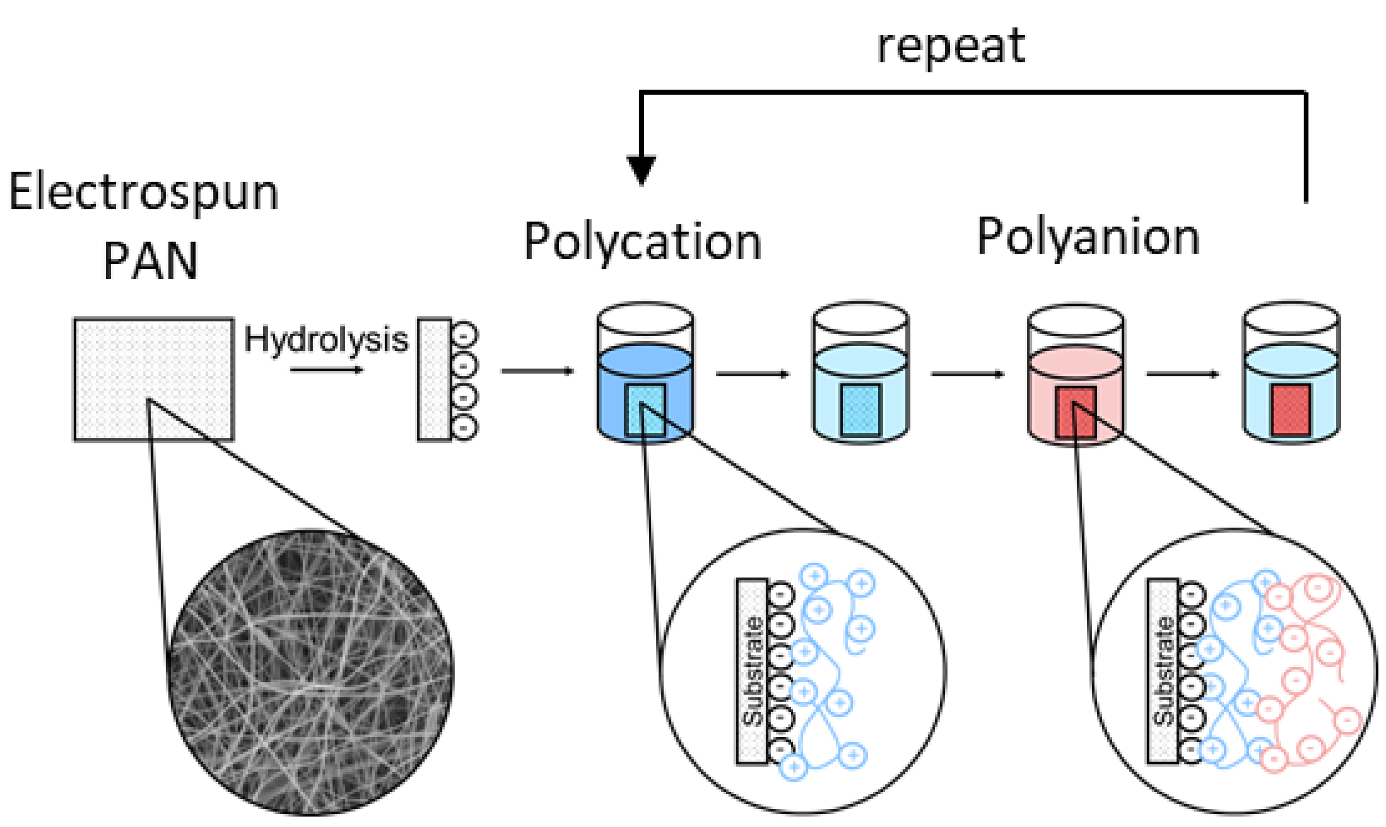



### 2. Hydrolysis of the support

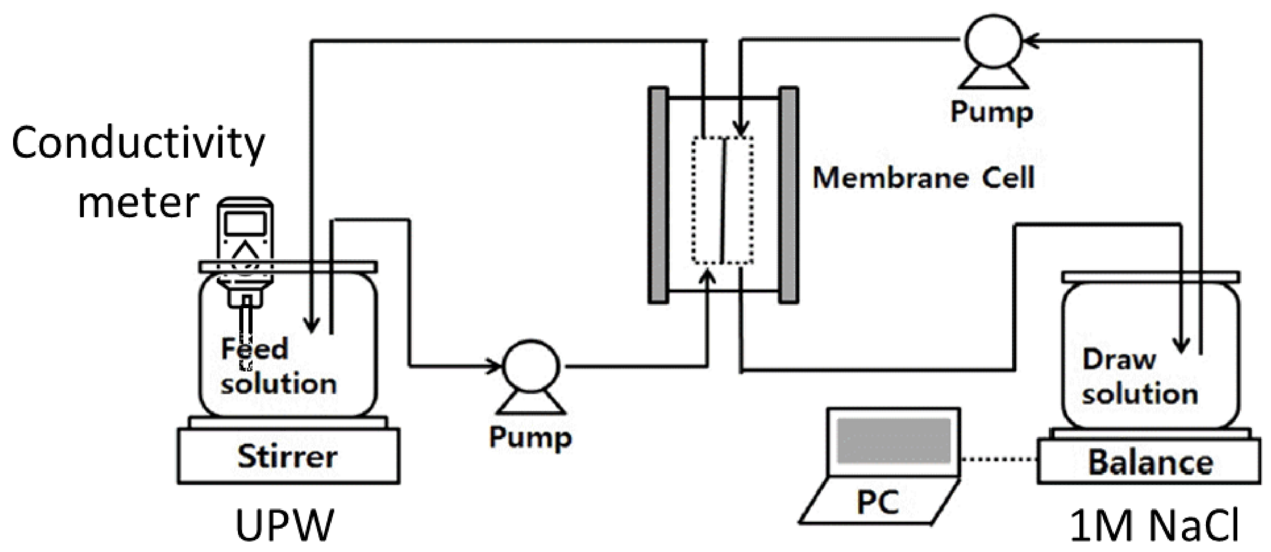



7h in 2M KOH @45 C

### 3. Optimization of LbL coating




### 4. Performance measurements




## Introduction

Water scarcity have led to a rapid development of desalination technologies. Among these technologies, forward osmosis (FO) systems have received great attention recently because it benefits from the naturally generated water diffusion from a low osmotic solution (feed) to a high osmotic solution (draw) through a semi-permeable membrane. FO systems have superior advantages like a high water recovery, a lower membrane fouling and a high energy efficiency.

## Project summary

The performance of current FO membranes, especially water fluxes ($J_W$), decreases due to internal concentration polarization (ICP) caused by inefficient membrane supports. Wire electrospinning produces highly open porous membrane supports that reduce the contribution of ICP thereby improving the $J_W$. For the selective active layer, a Layer-by-Layer (LbL) coating is suggested in order to decrease reverse draw solute flux ($J_S$) while further reducing the fouling sensitivity.

## Project goals

This research covers both material science and process technology. Depending on your own interest, you can focus on the development of the membrane support via electrospinning or the application of the active layer by the LbL coating using different polyelectrolyte couples while conducting the process performance measurements with an automated FO system.

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Membrane Materials and Processes

CHEMICAL ENGINEERING AND CHEMISTRY

## Membrane materials and processes

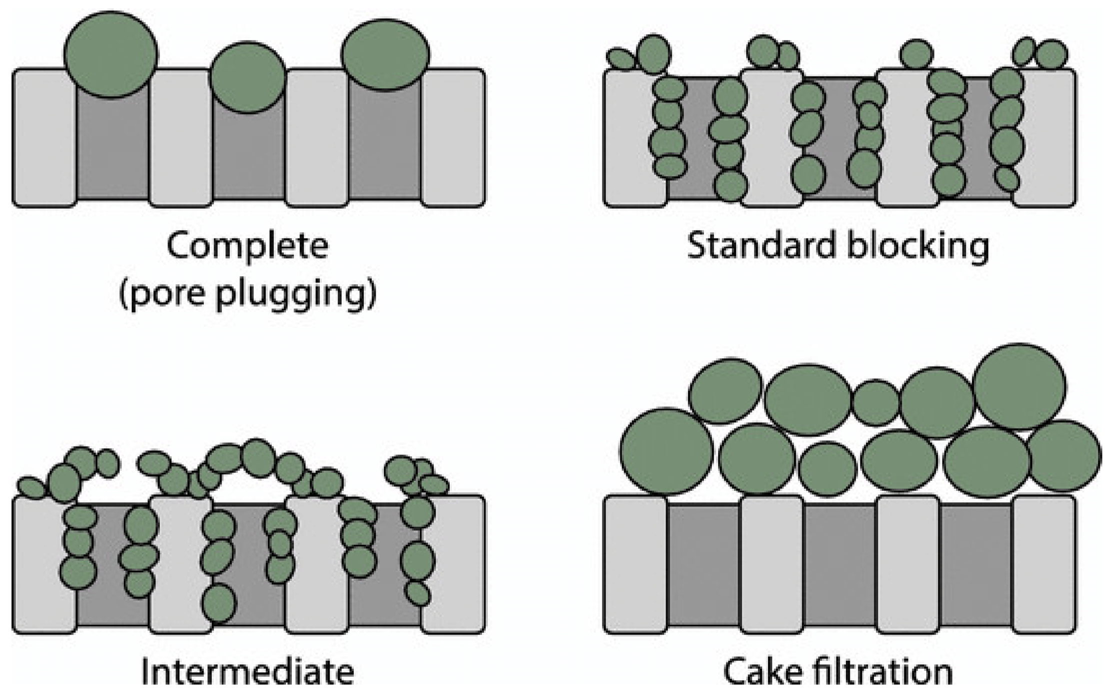
EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Ultrafiltration membrane modification for the forward osmosis applications

**Aylin Kinik, Zandrie Borneman, Kitty Nijmeijer**

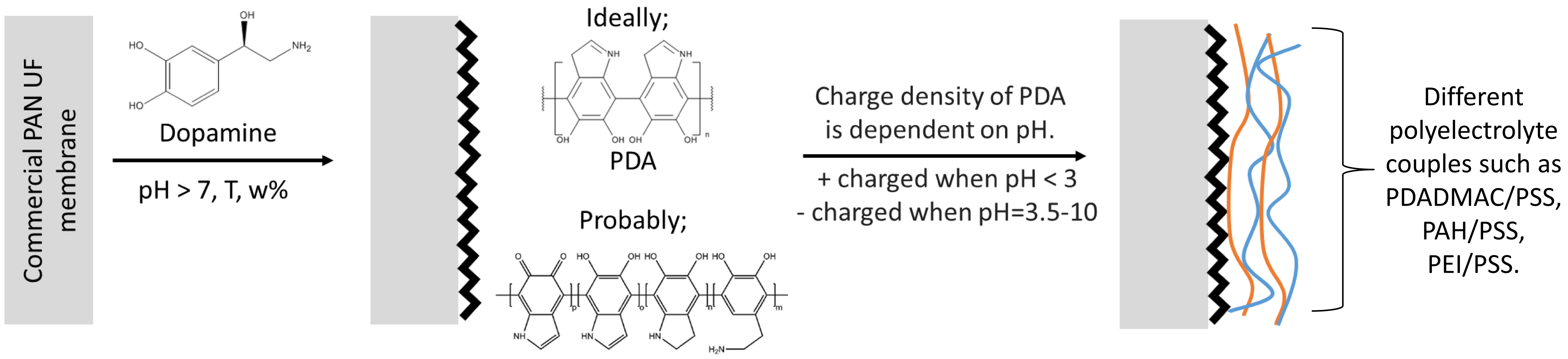
## Introduction

Forward osmosis (FO) systems are extensively studied for water purification and food processing. It has superior advantages like high a water recovery and lower energy consumption over conventional methods, membrane fouling has a negative effect on the performance. Therefore, fouling control is the key to cost-effective membrane operation.




Schematic representation of the fouling mechanisms

## Project summary




PDA with indole, catechol, quinone, and amine groups.

LbL coating

Modification of the membrane support by enhanced hydrophilicity resulted in improved anti-fouling properties. Polydopamine (PDA) molecule is well studied in the literature as a hydrophilic agent due to its easily tailored chemical structure based on different pH. Layer-by-Layer (LbL) method for the selective layer is suggested for improved selectivity due to tunable chemistry by means of pH, polyelectrolyte concentration, and number of layers.

## Project goals

First challenge of this project will be the optimization of PDA coating on a commercial support. After conducting different structural characterization methods (i.e. FTIR, FESEM, XPS), the membrane will be coated under different LbL conditions. It is then tested in an FO-system to determine its anti-fouling and selectivity properties.

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MMP Membrane Materials and Processes

CHEMICAL ENGINEERING AND CHEMISTRY

# Platinum group metal-free catalyst for next-generation polymer electrolyte fuel cells

Winnie Kong, Antoni Forner-Cuenca

## Introduction

Polymer electrolyte fuel cells (PEFCs) are promising for transportation applications, as they permit fast refilling, pollution-free and high-power operation. The fundamental challenge of applying PEFCs is the necessity of platinum as the electrocatalyst, which is costly, scarce and suffers from degradation. The current catalyst consists of platinum nanoparticles dispersed on carbon black and is bound with an ionomer to enable proton conductivity. Alternative electrocatalysts without noble metals will dramatically improve the cost-competitiveness of the technology. Platinum group metal-free catalysts consist of 3d-transition metals on carbon-based support, where the most promising metals are iron and cobalt.

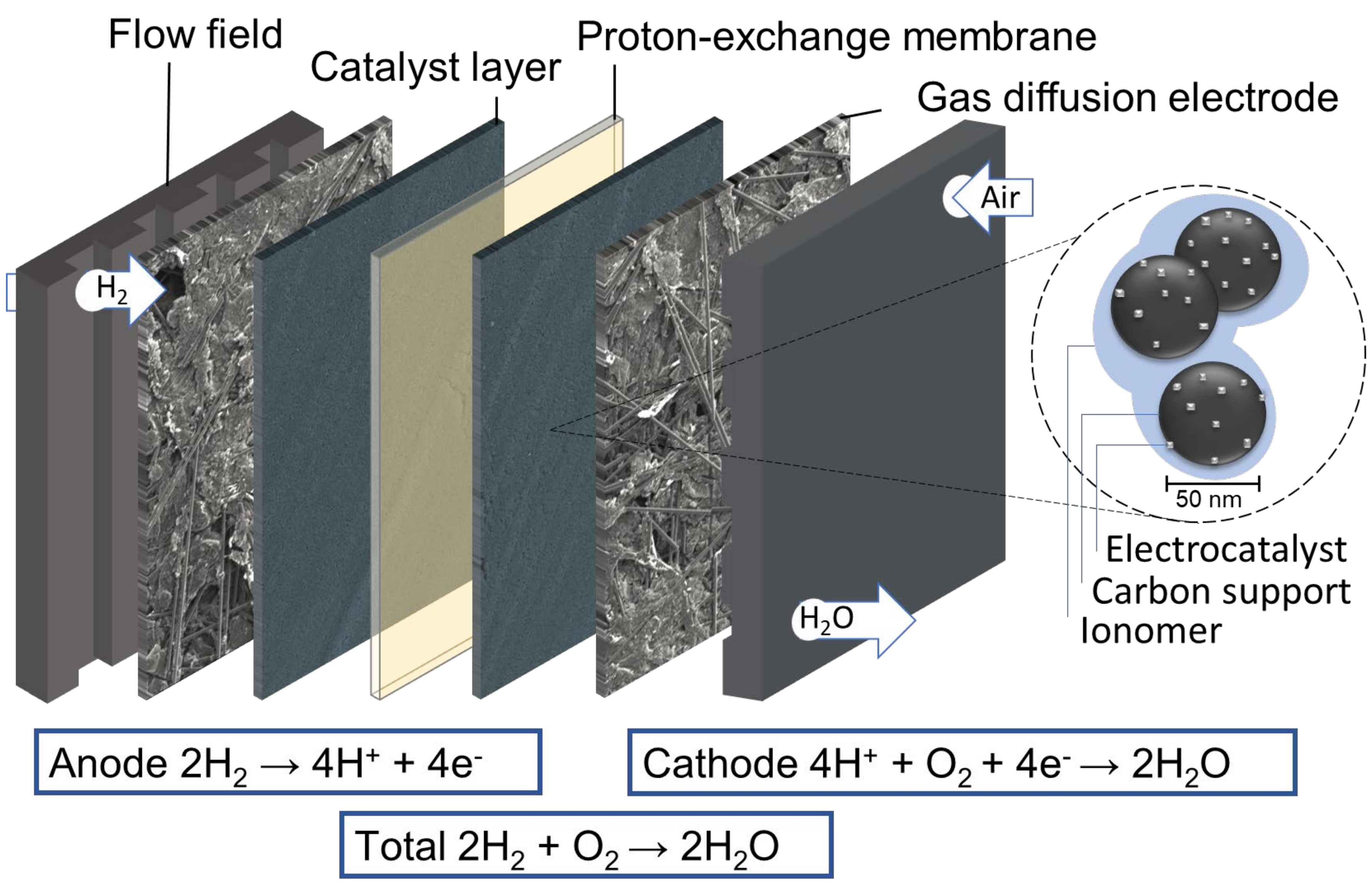


*Figure 1: Exploded view of the main components of the polymer electrolyte fuel cell.*

## Project summary

You will synthesize platinum-free catalysts and test their behaviour in 3 electrode set-ups to increase their durability and performance. The best catalysts will be tested in hydrogen fuel cells.

## Project goals

To engineer a platinum-free catalyst and make the PEFC more economically viable, you will:

- Synthesize platinum-free catalyst
- Evaluate their behaviour using the rotating disc electrode
- Tune the performance

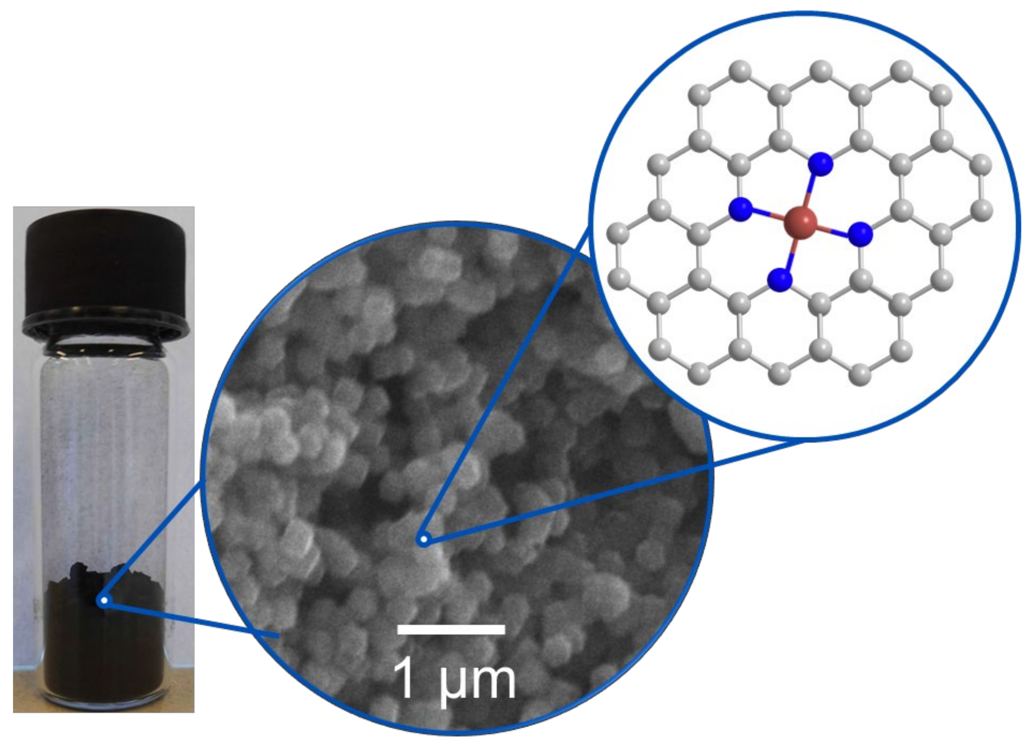


*Figure 2: Platinum-free catalyst: metal (red) – nitrogen (blue) moieties on carbon (gray) support.*

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Membrane materials and processes

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Electro-osmotic membrane dewatering of biomass

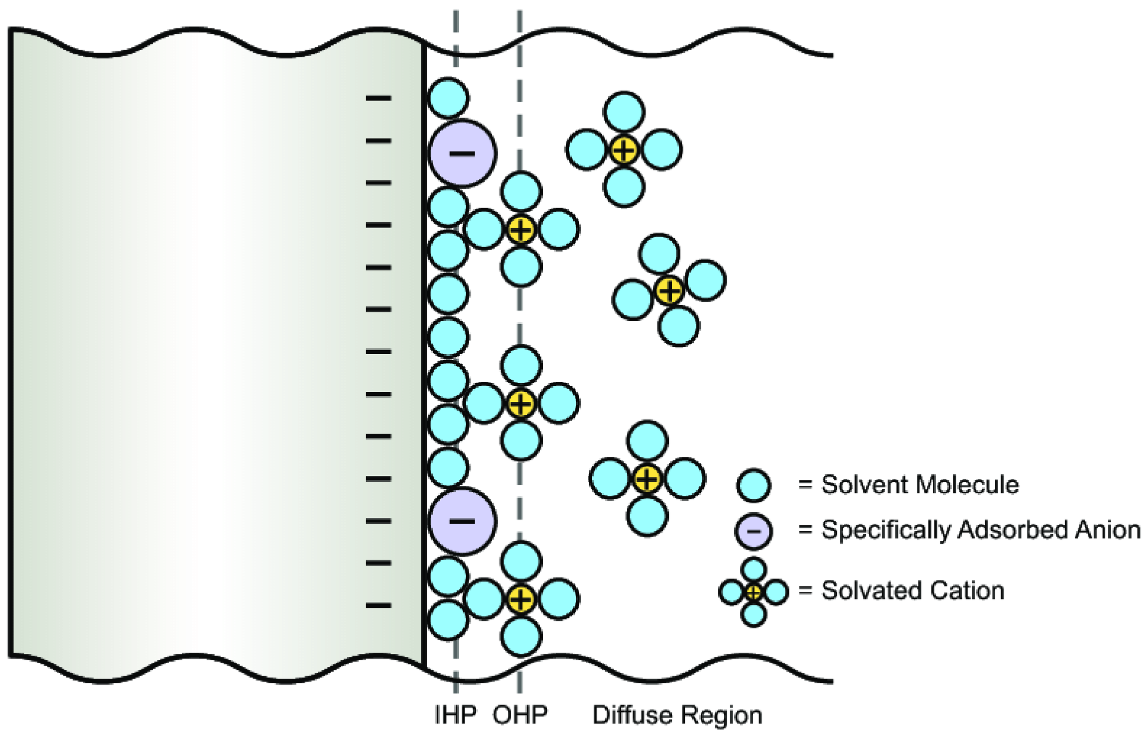
Sarthak Mehta, Zandrie Borneman and Kitty Nijmeijer

## Introduction

Bio-based materials are a sustainable alternative to fossil-based materials. These bio-based materials contain significant amounts of water and need to be dried to be used effectively. However, drying is an energy intensive operation accounting for roughly 20% of the industrial energy consumed globally. This project aims on developing energy efficient electro-osmotic dewatering techniques to enable a sustainable transition towards bio-based materials.

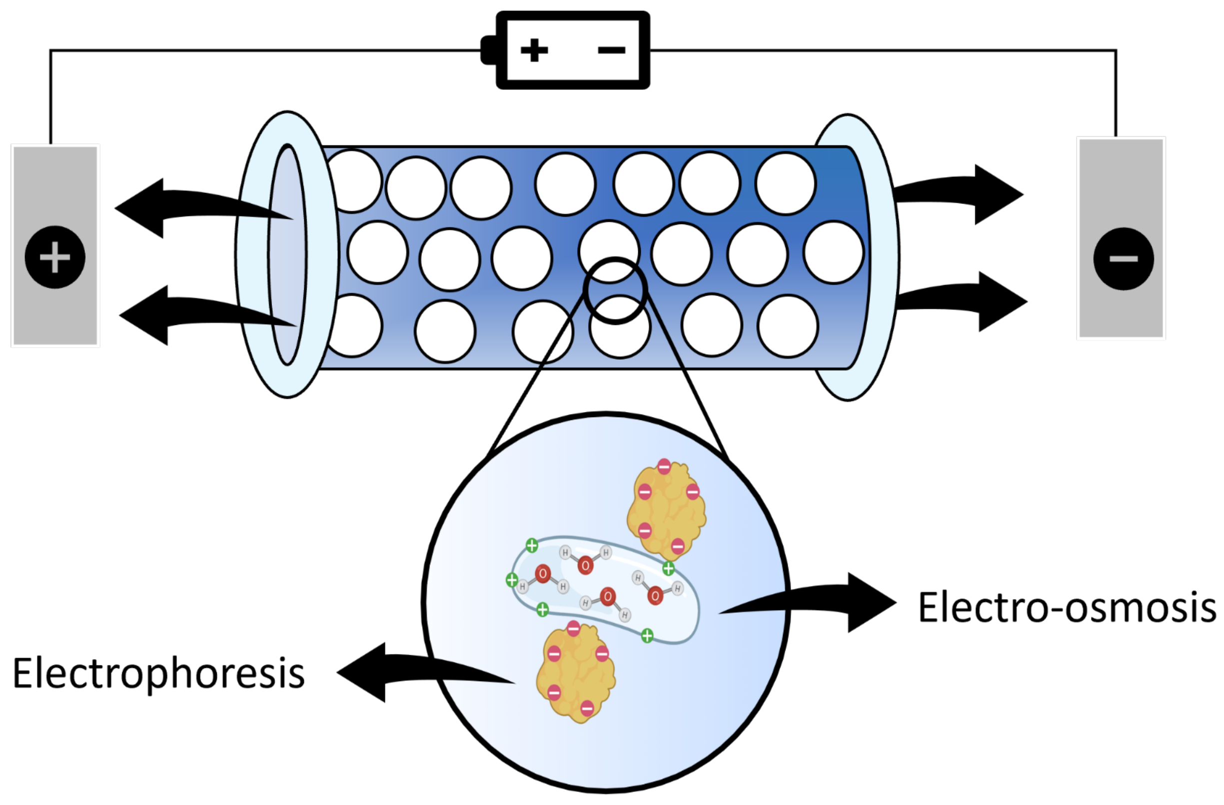
## Project summary

Biomass surface when exposed to an aqueous media, develops surface charges, forming an electric double layer (EDL) at the interface. The EDL extends into the bulk liquid as a diffusive layer of charged molecules. Under the influence of an external electric field, the charged molecules in the diffusive layer are pulled towards the oppositely charged electrode. This migration of the charged molecules in a slipping is followed by the adjacent bulk liquid and is referred to as an electro-osmotic flow.




*Electric double layer at the biomass-water interface*

*(Franklin et al. (2010), University of Michigan)*




*Electro-osmotic flow under the influence of an external electric field.*

## Project goals

In this project we will study the role of parameters (such as electric potential, pH, and particle size) that contribute to electro-osmotic flow in a packed bed. Characterization techniques used in this study include, cyclic voltammetry, impedance spectroscopy and streaming potential. If interested, feel free to contact me for more information.

## Contact information

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MMP Membrane Materials & Processes

EMS ELECTROCHEMICAL MATERIALS AND SYSTEMS

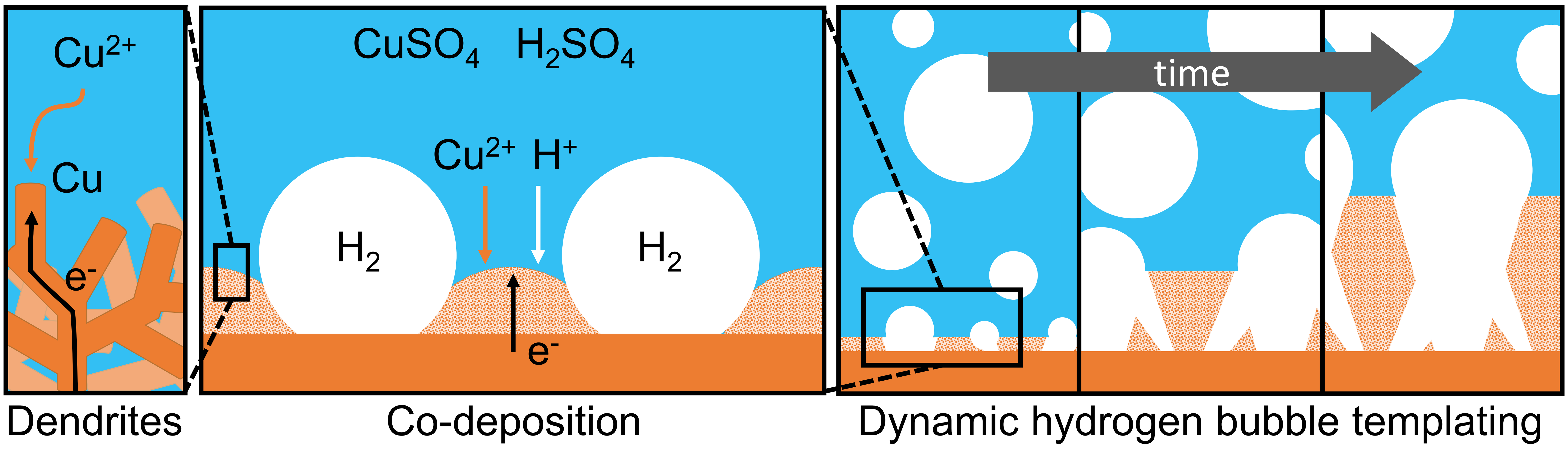
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Small scales at large scale - Upscaling of electrochemical material synthesis


Adrian Mularczyk and Antoni Forner-Cuenca


## Introduction

Dynamic hydrogen bubble templating (DHBT) is a novel approach to generate highly porous structures with pore sizes on both the micro and nano scale. This material structure has promising applications in electrochemical systems due to its binary structure acting as transport pathways to manage the flow of chemicals.



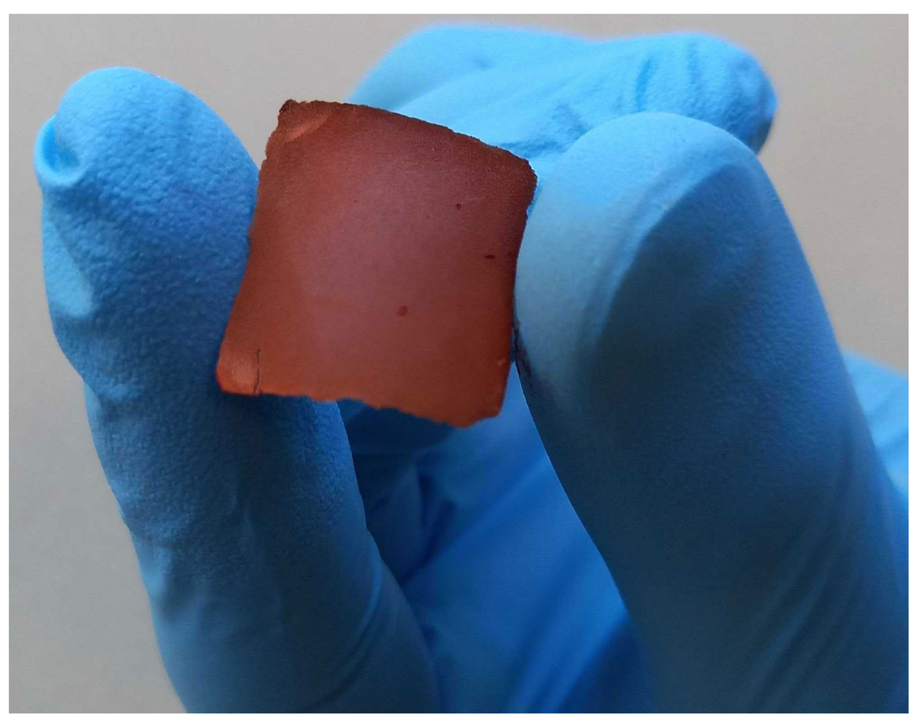

## Project summary

Currently, the material is produced as 4 cm² sized sheets in a batch process which limits further development and is resource intensive. Improving the synthesis to a continuous method, makes it possible to generate large amounts of the material and offers interesting opportunities to recycle and reuse the chemicals used to produce the foam.

## Project goals

Building on the current state of the project, you will be in charge of implementing an upscaled synthesis based on linear motion between the working and counter electrode.

- Development and characterization of **moving deposition** setup using linear actuators.
- Analyze the resulting material to ensure successful **transfer from batch to continuous synthesis.**
- Investigate options to **recover and recycle the chemicals** used during the deposition process.



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EMS — ELECTROCHEMICAL MATERIALS AND SYSTEMS

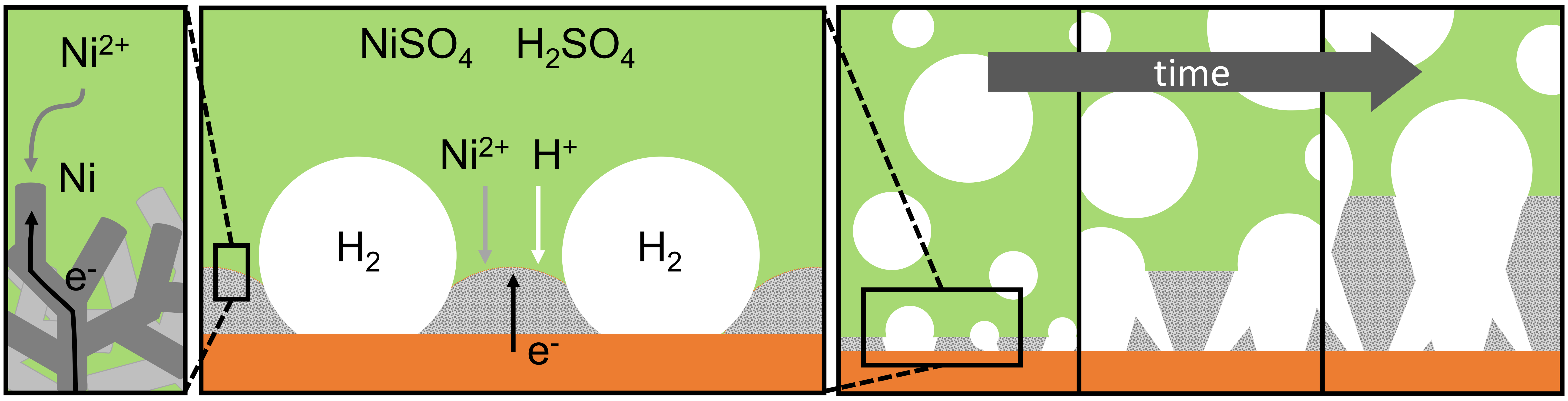
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Development of nickel foams produced using DHBT

Adrian Mularczyk and Antoni Forner-Cuenca

## Introduction

Dynamic hydrogen bubble templating (DHBT) is a novel approach to generate highly porous structures with pore sizes on both the micro and nano scale. This material structure has promising applications in electrochemical systems due to its binary structure acting as transport pathways to manage the flow of chemicals.




Dendrites — Co-deposition — Dynamic hydrogen bubble templating

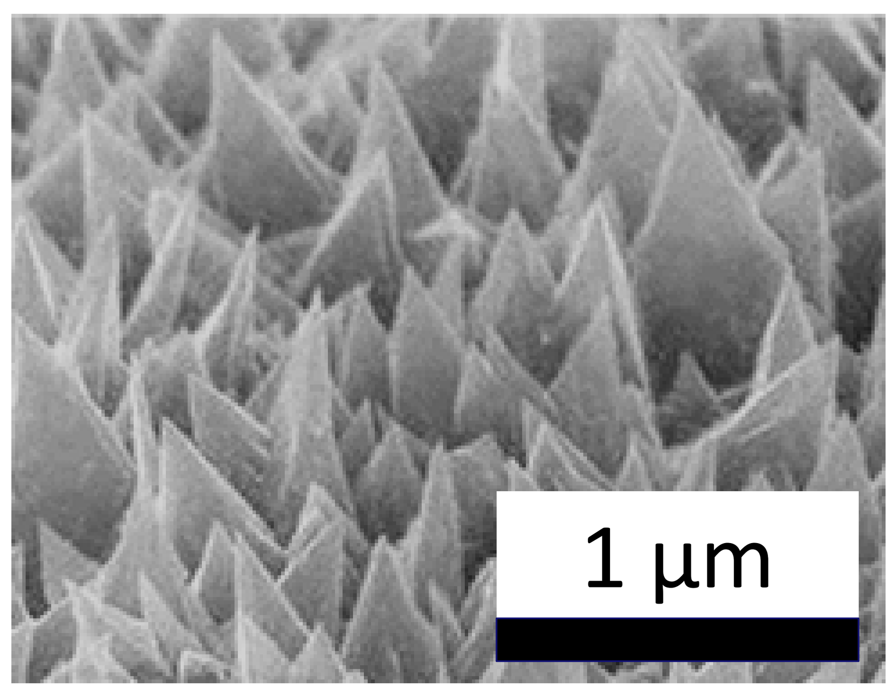
## Project summary

While the synthesis of DHBT foams from copper is well established and characterized, foams made from other metals, specifically nickel, have promising applications in the field of alkaline electrolysis. The transfer to another metal is however not trivial and requires adaptation of the synthesis parameters to produce high quality foams.

## Project goals

You will be in charge of evaluating critical parameters related to the synthesis of DHBT foams how they can be adjusted to facilitate the production of foams from nickel.

- **Evaluate the synthesis of nickel foams** from solution under conditions established for copper foams.
- **Adjust critical parameters** such as solution composition and concentration, to **tune the resulting structure**.
- **Derive standard operating procedures** related to the generation of nickel foams using DHBT.

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CHEMICAL ENGINEERING AND CHEMISTRY

Membrane Materials and Processes

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Covalent adaptable networks for fabrication of recyclable membranes

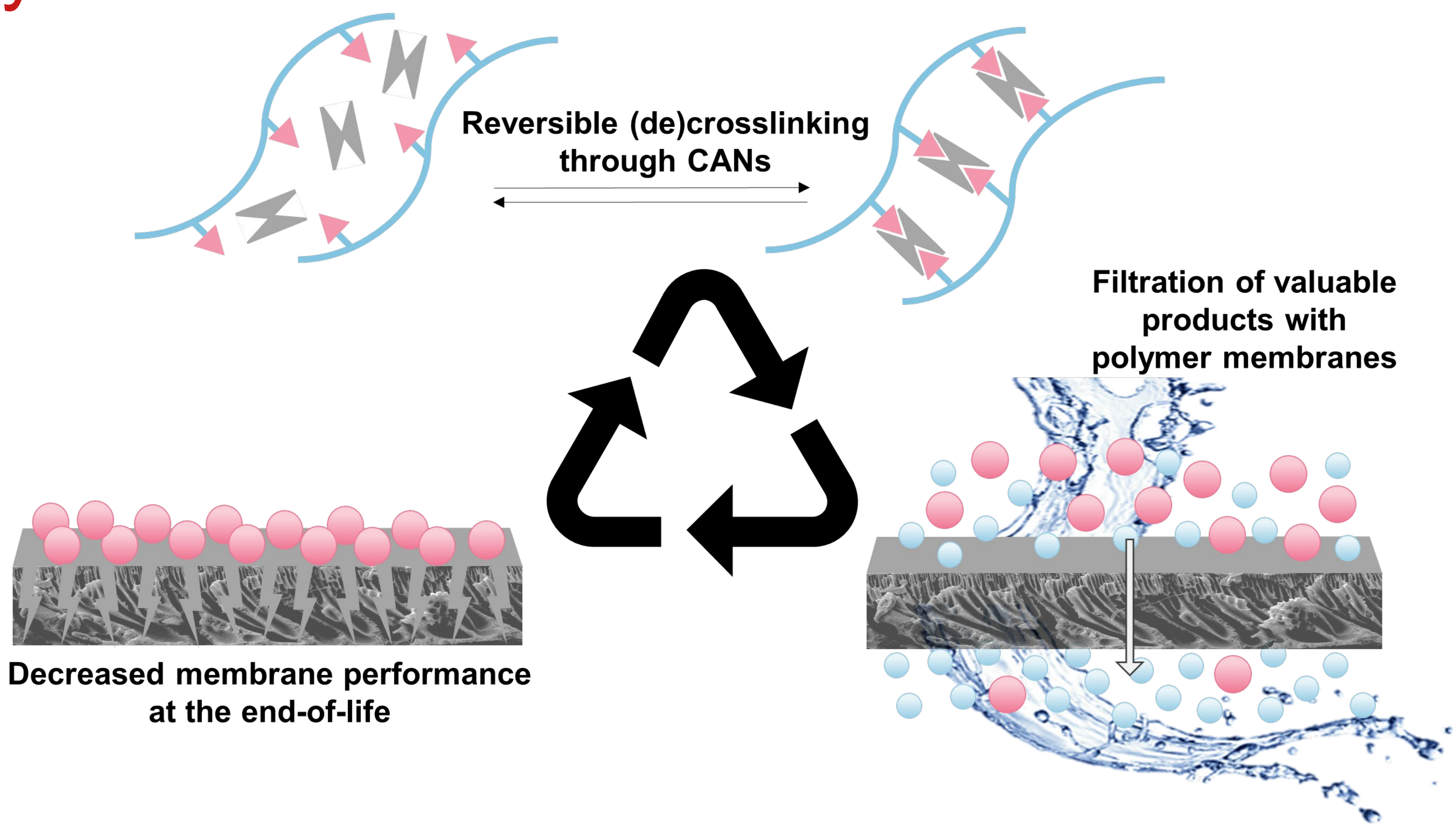
Jadwiga Poniatowska, Zandrie Borneman, Kitty Nijmeijer

## Introduction

Membranes are used in many industries (water treatment, pharmaceuticals purification, food production, electrochemical processes) as a more energy-efficient and sustainable alternative to thermal separation methods (distillation, drying). Many commercial membranes consist of crosslinked polymers, which allow for long-term chemical stability and favorable performance. However, crosslinked polymeric membranes are not recyclable, which often means they would be disposed through incineration or landfill.

## Project summary

Within the project, covalent adaptable networks (CANs) are used to fabricate recyclable and chemically stable membranes. CANs use dynamic covalent bonds that can be reversed upon application of an external stimulus (e.g. heat or light), thereby opening up the possibility of recycling and reprocessing membranes at their end-of-life.




## Project goals

In this interdisciplinary project (which can be tailored towards students on both MSMC and CPT track), you have an opportunity to fabricate recyclable membranes based on covalent adaptable networks:

- Polymer synthesis, purification and characterization ($^{1}$H and $^{13}$C NMR, GPC, TGA, DSC)
- Membrane fabrication (through non-solvent induced phase separation) and characterization (SEM, contact angle)
- Reversible crosslinking and closed-loop recyclability (ATR-FTIR, UV-Vis, gel content)
- Membrane performance testing using high-pressure dead-end filtration set-up

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CHEMICAL ENGINEERING AND CHEMISTRY


MMP

Advanced Research Center
Chemical Building Blocks Consortium

Electrochemical Materials and Systems

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Designing microstructured electrodes for long duration iron-air flow batteries

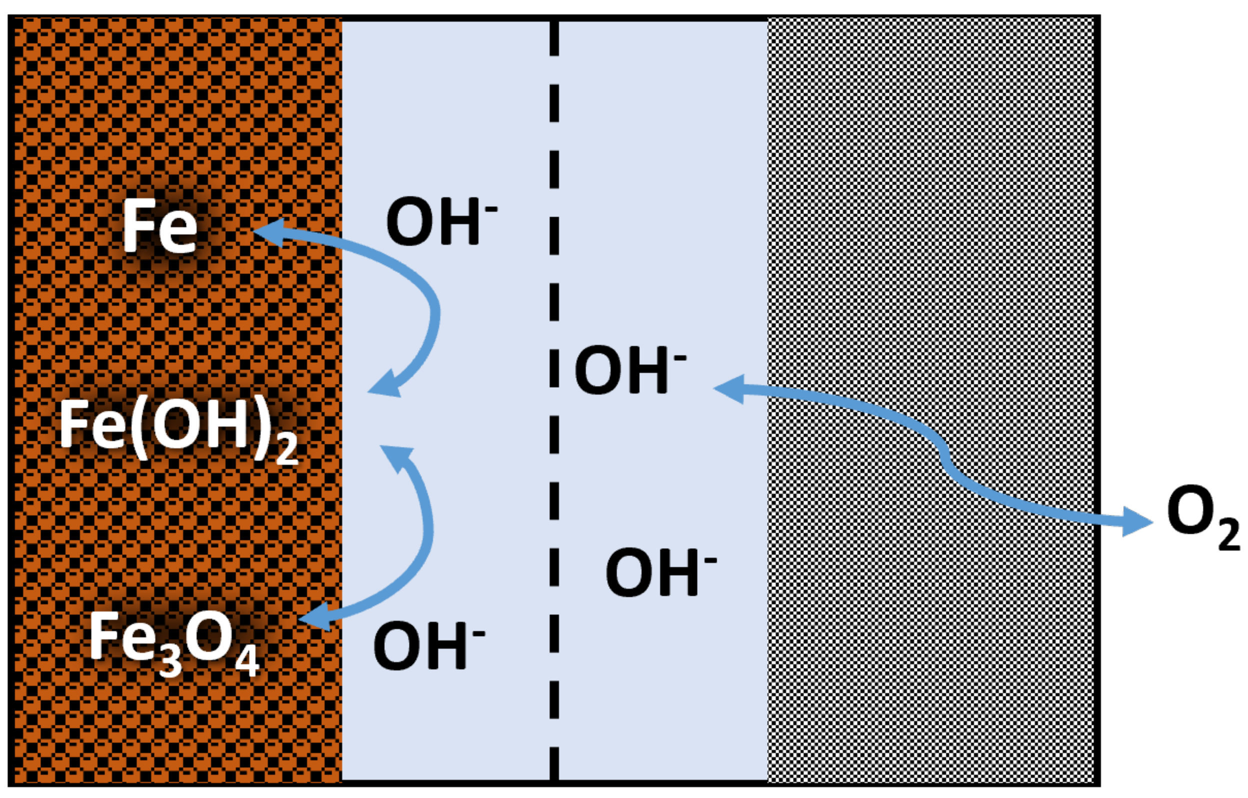
Marina Tabuyo-Martinez, Antoni Forner-Cuenca

## Introduction

The widespread development of renewable energy sources is key to decarbonize energy generation, but it requires more efficient energy storage technologies to meet consumption needs. Redox flow batteries are promising for grid-level electricity storage if cost-competitive systems are designed. Thus, iron-air flow batteries are attractive technologies as they have high energy density together with large availability and low cost of raw materials.

## Project summary

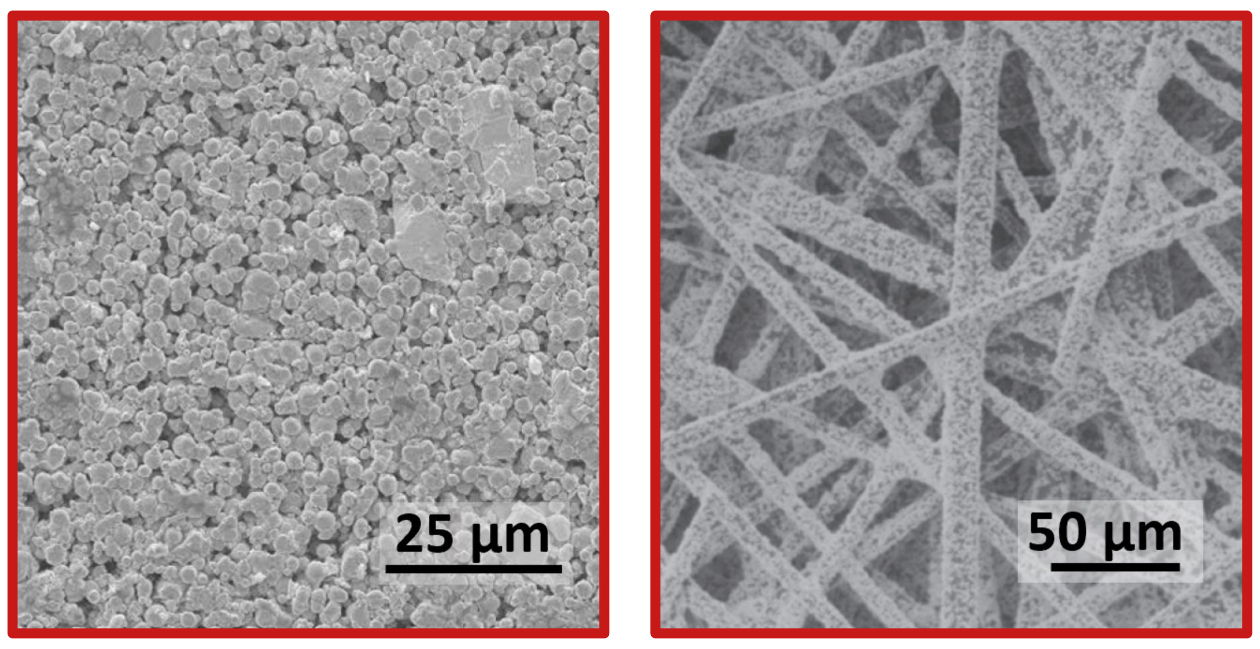
When developing iron-air flow batteries, several challenges arise. In this alkaline systems, iron anodes are dense, compact electrodes in which mass transport and active material utilization are limited. Therefore, engineering microstructured electrodes with higher iron and electrolyte accessibility is key to improve the battery performance. Moreover, modifications in the electrode surface would greatly influence transport phenomena, kinetics, and durability leading to an enhancement in capacity and cyclability.




*Scheme of an iron-air battery and its main reactions.*

## Project goals

You will develop microstructured iron electrodes with improved performance for iron-air flow batteries. To achieve this goal, you will manufacture iron electrodes, characterize them by physical, chemical and electrochemical techniques, and study their performance in iron-air flow batteries.




*SEM images of a dense electrode (left-Weinrich et al. 2018) and an iron-loaded carbon paper (right-Tan et al. 2019).*

## Contact information

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ems

## Membrane materials and processes

EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Process development for nutrient separation from manure digestate

**Marrit van der Wal, Zandrie Borneman and Kitty Nijmeijer**

## Introduction

The agricultural sector has a responsibility to contribute to the societal challenges of limiting nitrogen and (climate driven) $CO_2$ emissions into the atmosphere. In addition, the agricultural sector aims to valorize its liquid manure streams by producing high concentrated mineral streams next to nitrogen (N) and potassium (K) rich fractions.

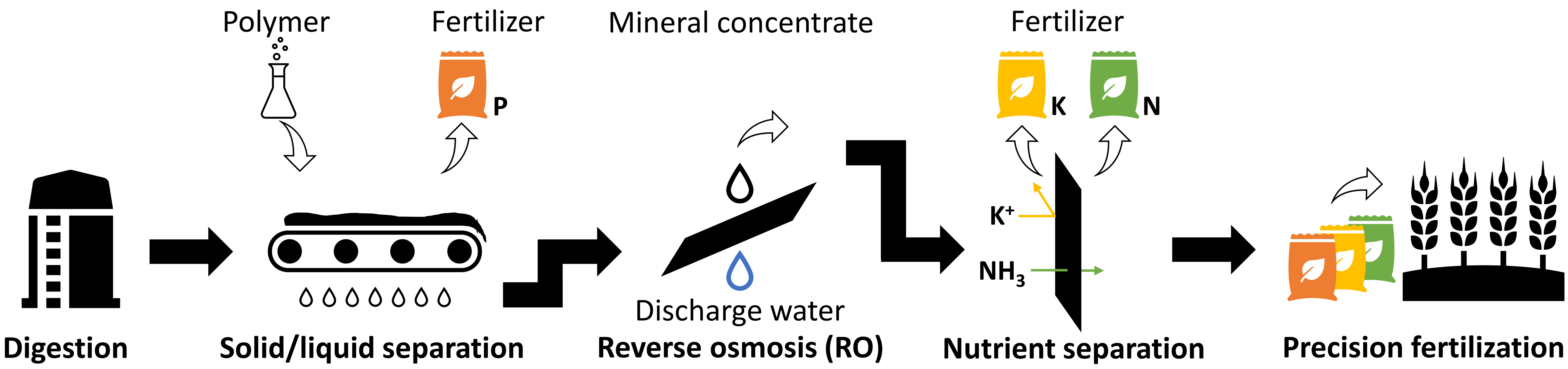


Figure 1: Schematic manure treatment process to produce separate nutrient-rich fractions.

## Project summary

This project focuses on improving and developing the liquid manure treatment processes to produce concentrated mineral streams and simultaneously fractions rich in N or K. The concentration factor and nutrient separation are based on the membrane characteristics and feed conditions which will be investigated. Membrane modification by adding a top layer through layer-by-layer polyelectrolyte deposition, electrospinning or spray coating further improves the retention and selectivity for separation.

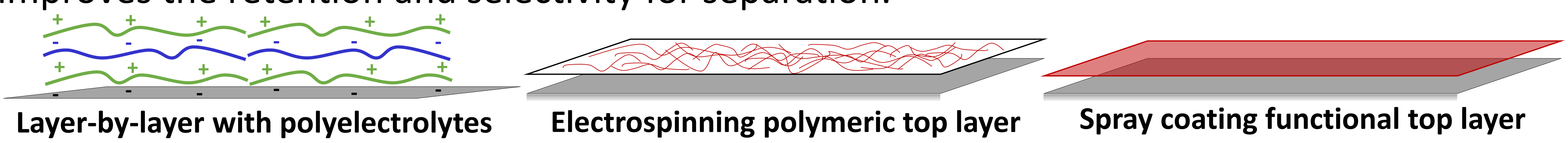


Figure 2: Different membrane modification options to improve N and K separation.

## Project goals

In your project, you will work membrane modification and/or increasing process efficiency. The research approach can be adapted to fit as a bachelor or master project.

## Contact information


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Membrane Materials and Processes

Membrane Materials and Processes

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european centre of excellence for sustainable water technology

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# Development of biobased PHA membranes using non-halogenated solvents

Liang-Shin Wang, Alan Werker, Zandrie Borneman, Kitty Nijmeijer

## Introduction

Membrane technologies are well-established, with a small footprint, ease of use, and low energy consumption. However, current fabrication processes typically require toxic solvents, and petrol-based polymeric materials are also used. The current production methods and materials have risks of negative environmental and health impacts. A transition to realize societal benefits in a circular economy necessitates the development of more sustainable and environmentally friendly production methods and materials for membrane technologies.

## Project summary

Polyhydroxyalkanoates (PHAs), fully biodegradable and biobased polymers, may be one alternative class of naturally occurring materials for membrane applications. PHAs can be produced inherently by bacteria coming from wastewater treatment processes. PHA-based membrane applications research showed promising results. However, developments are still at an early stage. Ways for systematic control of the polymer properties coupled with innovations for quality control in polymer recovery and membrane production process need further attention.

This project focuses on material characterization and membrane formulation at a laboratory scale. The objective is to investigate couplings between the formation process and the resulting membrane properties.

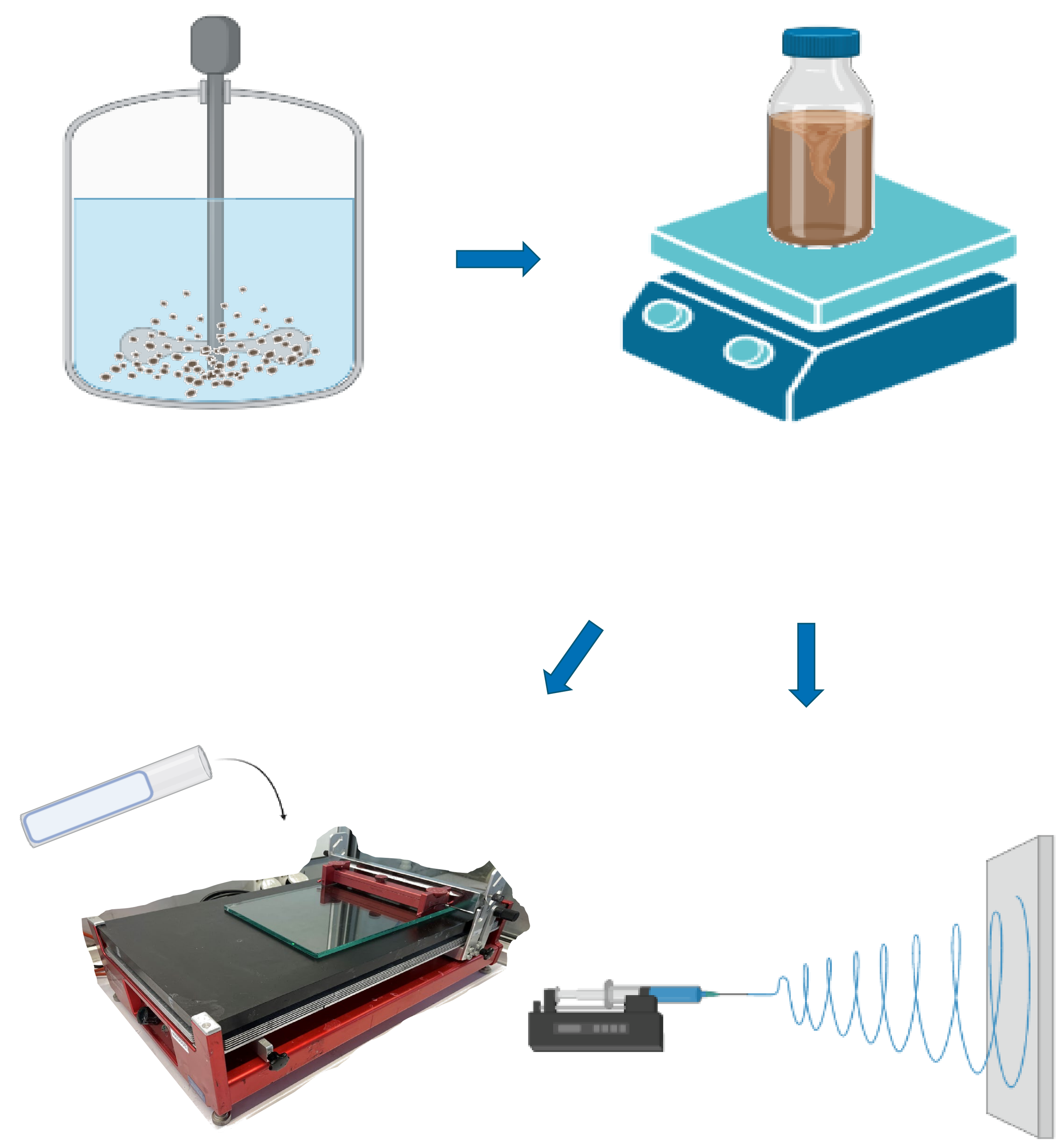

Figure 1: Schematic PHA downstream processing together with membrane formation.

## Project goals

Depending on your preferences, two types of projects are foreseen:

- Membrane development: linking of outcomes between production and properties.
- Membrane performance evaluation for nanofiltration applications.

## Project offers

- Allowance:
  €200-400 per month, subject to the personal situation.
- Location:
  Wetsus, Leeuwarden, Netherlands

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