UNIVERSITÀ DEGLI STUDI DI PADOVA

Title	**Functional Frameworks for Enhanced Anion Exchange in Electrochemical Membranes**

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International Secondment	
PI	Francesco Carraro
Institute	Graz University of Technology
Place, country	Austria
# months (min.3)	3

Introduction

The development of advanced membranes for electrochemical applications, particularly in **Anion Exchange Membrane Water Electrolysis (AEMWE)** and related technologies, is a crucial area of research. Hydrogen-bonded Organic Frameworks (HOFs), Covalent Organic Frameworks (COFs), and Metal-Organic Frameworks (MOFs) have emerged as promising materials due to their tunable chemical properties and high ion transport capabilities.

This PhD project aims to synthesize, deposit, and characterize these frameworks to improve **anion exchange efficiency** and membrane stability. Moreover, **polymer-grafted frameworks** will be synthesized to promote the integration and uniform distribution of frameworks in polymer matrices. The goal is to develop a next-generation membrane that enhances ion transport and electrochemical performance in alkaline environments.

Research Objectives

The key objectives of this research are:

- To synthesize HOFs, COFs, and MOFs with tailored properties for **anion transport** in alkaline conditions.
- To develop optimized **deposition techniques** for integrating these frameworks into membranes.
- To grow **polymer brushes** with tailored structural features from functionalized frameworks and determines their film-forming properties.
- To characterize the structural, chemical, and electrochemical properties of the resulting composite membranes.
- To investigate the interaction between the frameworks and membrane matrices for enhanced **hydroxide ion conductivity** and durability.
- To test the final membranes in **AEMWE** and other electrochemical applications.

Methodology

Synthesis of HOFs, COFs, and MOFs

The project will begin with the tailored synthesis of HOFs, COFs, and MOFs incorporating functional groups that enhance **hydroxide ion transport** and chemical stability. Various synthesis techniques, including solvothermal, hydrothermal, and mechanochemical methods, will be optimized. Selected frameworks will be chemically modified to introduce suitable functionalities to initiate controlled radical polymerizations. Polymer-grafted frameworks will be obtained with tunable length and density of polymer chains.

Deposition Techniques

To achieve stable and efficient integration of frameworks within membrane matrices, different **deposition techniques** will be explored, including:

- **Spin coating**
- **Layer-by-layer assembly**
- **Dip coating**

The possibility of employing polymer-grafted frameworks to directly form membranes by drop casting or spin coating with no additional polymer matrix will be explored. These methods will be optimized to ensure strong adhesion, uniform distribution, and minimal resistance to ion flow.

Characterization

A comprehensive suite of techniques will be used to evaluate the structure and properties of the developed materials:

- **Scanning Electron Microscopy (SEM):** Surface morphology and uniformity analysis.
- **X-ray Diffraction (XRD):** Crystalline structure identification.
- **Fourier-Transform Infrared Spectroscopy (FTIR):** Functional group and bonding analysis.
- **Thermogravimetric Analysis (TGA):** Thermal and chemical stability assessment.
- **Anion Conductivity Measurements:** Evaluation of hydroxide ion transport efficiency.
- **Electrochemical Performance Tests:** Measurement of ion exchange kinetics and durability under AEMWE conditions.
- **Nuclear Magnetic Resonance (NMR):** Characterization of polymer and composite materials structure.

Performance Evaluation

The synthesized membranes will be tested in **AEMWE cells**, focusing on:

- **Hydroxide ion conductivity**
- **Membrane resistance and efficiency**
- **Long-term stability in alkaline conditions**

Comparative studies with existing anion exchange membranes will help assess the improvements achieved through the incorporation of HOFs, COFs, and MOFs.

International Secondment Period

A three-month research visit at the **University of Graz** under the supervision of Dr. Francesco Carraro will be dedicated to advanced **deposition techniques** and **specialized characterization**, further enhancing membrane performance.

Expected Outcomes

This research is expected to deliver:

- Novel **anion-exchange-enhanced** HOFs, COFs, and MOFs.
- Optimized **deposition methods** for membrane fabrication.
- High-performance membranes with superior **hydroxide ion conductivity** and durability.
- Improved electrochemical efficiency in **AEMWE** and related applications.

Conclusion

This PhD project will contribute to the advancement of **anion exchange membrane technology** by integrating **functionalized frameworks** into electrochemical membranes. The outcomes will support the development of **highly efficient and durable** materials for next-generation **water electrolysis** and other alkaline electrochemical processes.