Electrochemical CO2 valorization to non-precious metal catalysts: synthesis, catalysis, and mechanistic studies

Summary

The National Institute of Chemical Physics and Biophysics (NICPB) is seeking a PhD candidate to join a multidisciplinary team working on converting carbon dioxide (CO2) into value-added carbon materials via molten salt electrolysis (CO2MSE). The project will explore how the electrochemical environment influences carbon nanostructure formation, and how these structures can be used to design non-precious metal catalysts for next-generation energy devices such as fuel cells and batteries. This position offers a unique opportunity to contribute to the fundamental understanding and applied development of carbon-negative energy technologies. The successful candidate will address the following core research questions: 1. How do electrode materials, electrolyte composition, and electrochemical parameters govern the morphology, structure, and properties of CO2-derived carbon materials? 2. Can operando spectroelectrochemical techniques reveal the mechanistic pathways of carbon growth? 3. How can the structure–function relationships of CO2-derived carbon materials be optimized to enhance the performance of non-precious metal catalysts in fuel cell and electrocatalysis applications?

Research field:	Chemical, materials and energy technology
Supervisors:	Kätlin Kaare Sander Ratso
Availability:	This position is available.
Offered by:	School of Engineering National Institute Of Chemical Physics And Biophysics
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The research

This PhD project investigates the electrochemical transformation of CO_2 into functional carbon materials using CO2MSE. The focus is on understanding and controlling how carbon nanostructures form during electrolysis, and how they can be tailored for use in fuel cells and as non-precious metal electrocatalysts.

The first research question explores how electrode materials, electrolyte composition, and applied current/potential influence the morphology, structure, and catalytic properties of the CO_2-derived carbon. A variety of salts, dopants, and deposition conditions will be tested to synthesize graphitic, porous, or non-precious metal-doped carbons.

The second research question addresses whether operando spectroelectrochemical techniques, in particular Raman spectroscopy, can reveal the mechanistic pathways of carbon growth and catalyst formation in real time. The candidate will use a custom-built high-temperature Raman electrochemical cell to probe surface reactions and intermediates during electrolysis.

The third research question investigates how the structure to function relationships of these materials translate into electrochemical performance for the oxygen reduction (ORR), oxygen evolution (OER) and hydrogen evolution (HER) reactions for fuel cells and electrolyzers. The synthesized materials will be tested for catalytic activity, with the aim of matching or surpassing the performance of commercial platinum-based systems.

Responsibilities and (foreseen) tasks

- Explore the synthesis of doped and structurally controlled carbon nanomaterials from molten carbonate electrolysis.
- Develop non-precious metal catalysts using in situ doping during carbon growth.
- Study the performance of the synthesized materials in low-temperature fuel cells.
- Utilize cutting-edge operando spectroelectrochemical techniques (Raman microscopy coupled with electrochemistry) to elucidate the formation mechanisms of carbon nanostructures and their interaction with catalytic species.

Applicants should fulfil the following requirements:

- MSc in natural sciences, preferably in chemistry, materials science, chemical engineering, or a related field.
- Strong interest in electrochemistry, carbon materials, and sustainable energy technologies.
- Excellent level of English and a collaborative spirit
- Ability to work independently and as part of an interdisciplinary research team.
- Present research results in international journals and conferences.

(The following experience is beneficial:)

- Previous experience with electrochemical methods, ORR, OER, HER, fuel cell or battery systems is highly desirable.
- Proven track record of independently designing experiments and/or instrumentation.
- Experience in the physical characterization of carbon materials.
- Experience in working with molten salts or high-temperature chemical equipment.

We offer:

- A 4-year PhD position in a lab with cutting-edge infrastructure (including a new operando Raman spectroscopy lab).
- Active participation in multiple international collaborations.
- Work with unique molten salt electrolysis systems and energy devices.
- Opportunities for conference visits, research visits to partnering institutions.
- A dynamic, innovative research environment focused on real-world CO# mitigation technologies.

About the department

The National Institute of Chemical Physics and Biophysics (NICPB) in Tallinn, Estonia is an independent research institute, which carries out basic and applied research in materials science, genetic engineering and biotechnology, environmental technology, in the field of particle physics and informatics, employing researchers from all over the world. The Energy Technologies Laboratory (ETL) at NICPB focuses on furthering fundamental understanding of electrochemical processes both at low and high temperatures, recycling of Li-ion batteries and developing novel functional materials with a minimal CO_2 equivalent. Key aspects of the research at ETL include the synthesis of carbon nanomaterials from CO_2 and biomass, battery recycling and advanced electrochemical testing, physical characterization and production scale-up. Our core aim is to replace the high CO_2 equivalent carbon materials in fuel cells, batteries and supercapacitors with sustainable alternatives.

(Additional information)

For further information, please contact Sander Ratso sander.ratso@kbfi.ee

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