CO#-derived carbon as a platform for precious metal electrocatalysts: synthesis, mechanistic insights, and fuel cell applications

Summary

The National Institute of Chemical Physics and Biophysics (NICPB) invites applications for a PhD position within a multidisciplinary research team investigating carbon-negative routes to advanced electrocatalysts. This position will focus on the synthesis of CO2-derived carbon via molten salt electrolysis (CO2MSE), doping the carbon either in situ or after the synthesis, integration with precious metal nanoparticles (e.g., Pt, Pt-alloys), and its application in fuel cell or electrolyzer devices. Emphasis will be placed on enhancing catalyst durability, optimizing carbon supports, and probing reaction mechanisms for both the carbon deposition and low temperature electrochemistry via spectroelectrochemical techniques. The successful candidate will address the following research questions: 1. How can the structure, porosity, and graphitization of CO2-derived carbon supports be tailored to improve dispersion, activity, and durability of precious metal nanoparticles? 2. What synthesis routes and post-treatments enable the formation of stable Pt and Pt-alloy nanoparticles with optimal size, morphology, and interparticle spacing for long-term electrocatalytic activity? 3. How can operando spectroelectrochemistry elucidate degradation mechanisms and catalyst/support interactions in molten salt-derived electrodes?

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 will focus on integrating carbon synthesis with state-of-the-art strategies in precious metal electrocatalyst development for polymer electrolyte fuel cells. Building on recent advances in the CO2MSE process, the candidate will engineer CO_2-derived carbons with tunable graphitization, porosity, and surface functionality. These materials will serve as sustainable and corrosion-resistant alternatives to fossil-derived carbons in Pt- and Pt-alloy catalysts.

Key strategies will involve:

- Controlling catalyst particle size (~3–4 nm) and spacing to mitigate Ostwald ripening and agglomeration.
- Utilizing post-treatment methods or catalytically active substrates to introduce surface defects that enhance nanoparticle dispersion, lower necessary Pt loadings, and increase electrochemically active surface area (EASA).
- Developing Pt intermetallic catalysts (PtCo, PtNi) to reduce Pt loadings necessary for high activity.

Parallel to material synthesis, the project will develop and apply in situ/operando spectroelectrochemical methods track the growth of carbon structures and monitor degradation pathways in real time. Mechanistic insights will guide material optimization, including the stability of Pt–carbon interfaces and catalyst-ionomer interactions.

The research will directly contribute to understanding durability constraints in heavy-duty fuel cell applications, addressing system-level challenges (catalyst corrosion, voltage cycling, and particle migration) that are exacerbated under long-haul conditions. The final aim is to benchmark these CO#-derived electrocatalysts against commercial Pt/C systems, with a focus on lifetime performance, power density, and sustainability.

Responsibilities and (foreseen) tasks

- Synthesize and post-treat CO#-derived carbon supports tailored for precious metal nanoparticle deposition

- Fabricate Pt and Pt-alloy catalysts
- Characterize catalysts using electrochemical and physical characterization methods
- Evaluate catalyst performance in PEMFC-relevant ORR conditions using RDE and MEA testing
- Design and carry out spectroelectrochemical studies to understand catalyst/support interaction and degradation
- Present research results in international journals and conferences.

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.

(The following experience is beneficial:)

- Previous experience with electrochemical methods, 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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