CHEMICAL ENGINEERING

Ammin/CRT/DISAT - Development and optimization of a scalable co-electrolyzer for green fuels & chemicals production from water and CO2-based flue gas

Funded By	Dipartimento DISAT Politecnico di TORINO [P.iva/CF:00518460019] FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]

Supervisor	HERNANDEZ RIBULLEN SIMELYS PRIS - simelys.hernandez@polito.it

Contact	

Context of the research activity	This PhD fellowship aims to develop and test reproducible and scalable electrocatalysts for the production of valuable green fuels and chemicals (i.e., green H2, syngas (CO+H2), formate, alcohols, oxo-products). Gas diffusion electrode-based electrolyzers and zero-gap systems will be investigated, as well as novel approaches to integrated CO2 capture and conversion processes that directly exploit renewable electricity sources. The proposed research plan is funded by Fondazione CRT and Qatar Research Development and Innovation Council (QRDI, project no ARG02-0312-240002). It strongly aligns with QRDI thematic area of the “Energy and environment” pillar and the thematic area “Carbon Capture & Utilization Technologies”.

	The key contributor to global climate change in the atmosphere is CO2. Its atmospheric level is increasing more than ever in the Earth's history: It reached 419 ppm in January 2023 and is likely to reach about 600 ppm by 2100, if CO2 emissions continue to follow the current trend. The European chemical industry heavily relies on H2 produced from sources (i.e., via steam methane reforming) and on carbon feedstock imports for energy and chemical manufacturing processes, which are based over 95% on the use of fossil fuels. Thus, 80% of EU energy system rely on fossil fuels that cause 80% of EU GHG emissions, while about 53% of the energy consumed in the EU is imported from outside countries. Exploiting sustainable chemistry, utilizing renewable resources and CO2 to produce chemical products, presents an opportunity for the efficient use of resources and environmental preservation. It will contribute to reducing greenhouse gases, in line with the commitments agreed in the 2021 Glasgow Agreement signed during the United Nations Climate Change Conference (COP26) and RePower EU directives. Carbon Capture and Utilization (CCU) is one of the significant technologies that could be addressed worldwide to mitigate CO2 emissions. Among

Objectives	different processes, the electro-catalytic reduction of CO_2 is an attractive solution that can be exploited as an efficient route to convert CO_2 into chemicals or fuels by using renewable electricity, water as a source of protons (H^+) and electrons (e^-) in the so-called “artificial photosynthesis”. In this way, CO_2 can be utilized as a feedstock in a circular economy perspective, transforming waste into valuable and value-added products to address both GHG emissions and energy problems related to fossil fuel dependence. The primary objective of this PhD is to investigate novel, low-cost, and abundant CO_2 reduction electrocatalysts with competitive activity and stability compared to state-of-the-art catalysts. The goal is to develop an integrated electrochemical system for CO_2 capture and conversion, using two different approaches: in the first one, the CO_2 capture medium will be used as the same electrolyte for the CO_2 reduction process; in the second one, the fluegas will directly be fed in the gas-phase to be separated and converted in a single and smart-designed co-electrolyzer. The practical application of the best integrated process will be pursued in integrated CO_2 capture and conversion devices under development at Politecnico di Torino, starting from a 120 cm^2 scale cell. The expected outcomes of the studies that will be performed are: • Develop and investigate the performance of new abundant and low-cost electrocatalysts for water splitting and electrochemical CO_2 reduction (EC CO_2R). • Development of gas diffusion electrodes and half membrane-electrode-assembly (MEA) by the coupling of the electrocatalysts and different ion exchange membranes (IEM). • Development of full-MEAs constituted by the OER electrode, the CO_2R electrode and the IEM. • Investigation of the catalyst’s performance in gas-phase GDE and zero-gap MEA electrochemical reactors. • Optimization of an innovative process coupling CO_2 capture and in-situ electrochemical conversion. A reactor prototype developed between the Politecnico di Torino and an industrial partner within the European project SunCoChem (https://suncochem .eu/) will be exploited. • Optimization of the process by tuning the reactor operating conditions (flow rates, pressure, temperature, applied potential, etc) to reach the target stability and electrochemical CO_2-to-fuels performance, under current density values (>100 mA/cm^2) that are relevant for an industrial application. Different instruments and characterization techniques (FESEM, XRD, XPS, among others) available at PoliTO-DISAT and CREST Group https://www.disat.polito.it/it/la_ricerca/gruppi_di_ricerca/crest (e.g. Solar-Fuels Lab) will be exploited for the study of the chemical-physical properties and electro-catalytic performance of the device. An electrochemical test bench designed and manufactured in the framework of the CO_2 Circle Lab (https://co2circlelab.eu/) will be used for the electrochemical activity tests and long-term stability studies. Products analysis will be performed by using analytical instruments, e.g. HPLC, GC-MSD with head-space, micro-GC, among others. The fundamental knowledge we have acquired in previous EU (e.g. SunCoChem, CELBICON, RECODE), industrial will be implemented to accomplish the goal. The outcomes from this PhD Thesis will be part of the start-up entrepreneurship project eCO2SYNTH, funded initially as a proof-of-concept (PoC) project by EUREKA Venture.

Skills and competencies for the development of the activity	- Knowledge of chemical engineering and/or industrial chemistry, or related disciplines, is mandatory. - A good background or previous studies in electrochemistry and electrochemical reactions are highly valuable. - Know-how and/or willing to learn electrochemical characterization techniques, electrocatalysts, and electrode preparation methods. - A good knowledge of standard practices and previous experience in chemical laboratories is required. - Ability to set priorities, work in a multicultural and multidisciplinary team, plan the work, and respect deadlines is essential.