CHEMICAL ENGINEERING

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 FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]
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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, along with 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 the Qatar Research, Development and Innovation Council (QRDI, project no. ARG02-0312-240002) in collaboration with Qatar University. 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 atmospheric global climate change is CO2. Its atmospheric level is increasing faster than at any time in Earth's history: It reached 419 ppm in January 2023 and is likely to reach about 600 ppm by 2100 if CO2 emissions continue at the current rate. 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 the EU energy system relies on fossil fuels, which account for 80% of EU GHG emissions, while about 53% of the energy consumed in the EU is imported from outside the EU. 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 gas emissions, in line with the commitments agreed in the 2021 Glasgow Agreement, signed during the United Nations Climate Change Conference (COP26), and the RePower EU directives. Carbon Capture and Utilization (CCU) is one of the significant technologies that could be addressed worldwide to mitigate CO2 emissions. Among different processes, the electro-catalytic reduction of CO2 is an attractive

Objectives	solution that can be exploited as an efficient route to convert CO2 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, CO2 can be utilized as a feedstock in a circular economy, transforming waste into valuable, value-added products to address both GHG emissions and energy problems associated with fossil fuel dependence. The primary objective of this PhD is to investigate novel low-cost, and abundant CO2 reduction electrocatalysts with competitive activity and stability compared to state-of-the-art catalysts. The goal is to develop an integrated electrochemical system for CO2 capture and conversion, using two different approaches: in the first one, the CO2 capture medium will be used as the same electrolyte for the CO2 reduction process; in the second one, the flue gas will directly be fed into 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 CO2 capture and conversion devices under development at Politecnico di Torino, ranging from 5 cm2 to >120 cm2-scale cells. 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 CO2 reduction (EC CO2R). • Development of gas diffusion electrodes and half membrane-electrode-assembly (MEA) by the coupling of the electrocatalysts and different ion exchange membranes (IEM). • Assessment of the performance in half- and full-cells, including the investigation of different CO2 absorbent-based electrolytes. • Investigation of the catalyst’s performance in gas-phase GDE and zero-gap MEA electrochemical reactors. • Optimization of an innovative process coupling CO2 capture and in-situ electrochemical conversion. A reactor prototype developed by 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 CO2-to-fuels performance, under current density values (>100 mA/cm2) that are relevant for an industrial application. Different instruments and characterization techniques (FESEM, XRD, XPS, among others) available at PoliTO-DISAT and the CREST Group (https://www.disat.polito.it/it/la_ricerca/gruppi_di_ricerca/crest, e.g., Solar-Fuels Lab) will be used to study the chemical-physical properties and electro-catalytic performance of the device. An electrochemical test bench, designed and manufactured within the framework of the CO2 Circle Lab (https://co2circlelab.eu/), will be used for electrochemical activity tests and long-term stability studies. Product analysis will be performed by using analytical instruments, e.g., HPLC, GC-MSD with headspace, 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.

	- Knowledge of chemical engineering and/or industrial chemistry, or related disciplines, is mandatory.

Skills and competencies for the development of the activity	- A good background or previous studies in electrochemistry and electrochemical reactions (e.g., CO2 conversion) 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.