Politecnico di Torino

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CHEMICAL ENGINEERING

PNRR/NEST - Direct electrocatalytic conversion of CO2 from flue gases to value-added products

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Context of the research activity	This PhD fellowship aims to develop a new concept of a renewable-electricity-driven electrocatalytic system for converting biogenic or fossil-fuel based CO2 streams to high added-value fuels and chemicals (i.e. syngas formate, alcohols, etc). The project is financed under the PNRR project: PNRR M4C2, Investimento 1.3 - Avviso n. 341 del 15/03/2022 - PE0000021 Network 4 Energy Sustainable Transition (NEST) - CUP E13C22001890001.

	The hydrogenation of CO2 to valuable products via electrochemical processes can be an interesting option to address the gigaton challenge of reducing greenhouse gases (GHGs) emissions. In the case of CO2¿¿¿the key contributor to global climate change in the atmosphere¿¿¿its atmospheric level is increasing more than ever in the history of the Earth: It reached 419 ppm in January 2023 and will probably reach about 600 ppm by 2100, if the CO2 emission continues to follow the current trend. Currently, the European chemical industry strongly depends on carbon feedstock imports for energy and chemical manufacturing processes, which are based over 95% on the use of fossil fuels. Besides, the EU energy system is 80% based on fossil fuels that cause 80% of EU GHG emissions, and about 53% of the energy consumed in the EU is imported from outside countries. Exploiting sustainable chemistry, using renewable resources and CO2 to produce chemical products, brings an opportunity for efficient use of resources and preservation of the environment. 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). Carbon Capture and Utilization (CCU) is one of the major technologies that could be addressed worldwide to mitigate CO2 emissions. Among different

Objectives	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 used as a feedstock in a circular economy perspective, transforming waste into useful and value-added products to tackle both GHG emissions and energetic problems related to the dependence on fossil fuels. The main objective of this PhD is to optimize a new concept electrochemical reactor for converting CO_2 coming from different flue gases, exploiting renewable electricity to produce high-value chemicals. The innovation of the proposed process lies in the efficient, sustainable, inexpensive and direct transformation of CO_2 into the gas phase, eliminating common limitations of other electrochemical systems and exploiting the actual synergies existing between the thermocatalytic and the electro-catalytic technologies, as well as the fundamental knowledge that we have acquired in the framework of previous EU projects (e.g. SunCoChem, CELBICON, RECODE) and industrial researches. The expected outcomes of the studies that will be performed are: ¿¿¿ Assess the performance of selected thermo-catalysts for the gaseous CO_2 electrochemical conversion to relevant products. ¿¿¿ Development of Gas Diffusion Electrodes (GDEs), composed of electrocatalysts and conductive porous supports. ¿¿¿ Development of half membrane-electrode-assemblies (MEAs) constituted by the CO_2 reduction electrocatalyst and an ion exchange membrane. ¿¿¿ Investigation of the GDE and zero-gap MEA reactor performances with the best catalysts. ¿¿¿ 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. ¿¿¿ Evaluate the influence of other gases and impurities present in biogenic CO_2 gas source (SO_x, O_2, N_2, CH_4, etc.) and correlate it with the process performance, for the future scale-up of the technology. 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.

Skills and competencies for the	- Knowledge of chemical engineering and/or industrial chemistry is mandatory. - A good background or previous studies in electrochemistry and electrochemical reactions is of high importance. - Know-how and/or willing to learn electrochemical characterization techniques, electrocatalyst and electrodes preparation methods.

for the development of the activity	- Good knowledge of standard practices and previous experience in chemical laboratories are desirable. - Ability to set priorities, work in a multicultural and multidisciplinary team, plan the work and respect deadlines are necessary. - Availability to work in lab or office in a full-time regime (8h a day x 5 days a week) is necessary.