Università di Genova | **DICCA** Ph.D. PROGRAM IN CIVIL, CHEMICAL AND ENVIRONMENTAL ENGINEERING

PhD Program in Civil, Chemical and Environmental Engineering
Curriculum in Chemical, Materials and Process Engineering

June 2024 Call, XL cycle - Starting date: November 1 st 2024

The research projects submitted for the admission to the PhD program must be prepared in accordance to one of the projects listed in this file, which are organized by general thematics. Click on the Thematic you are interested in to see the full list of projects.

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Projects in Plants and bioprocesses

Project: Treatment of agro-industrial wastewaters and emerging pollutants using microalgae

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Thematic*: *Projects in Plants and bioprocesses

Project: Treatment of agro-industrial wastewaters and emerging pollutants using microalgae

Keywords: photobioreactors, new plant development, microalgal biomass exploitation, lipid recovery.

Brief Description:
The increasing of urbanization and industrialization leads to the production of large quantities of wastewater around the world. Part of this waste can be exploited for the growth of microalgae, reducing their cultivation costs, and making chemicals recovery and biofuel production more feasible.

Using the mixotrophic metabolism, microalgae are able to absorb and use many of the organic molecules contained in wastewater, reducing its polluting load, leading to the production of additional microalgal biomass and to the purification of the water used.

After the growth, the microalgae biomass can be collected and used for the production of biofuels and for the recovery of chemicals of interest.

Batch and continuous microalgal growth systems are available in the laboratory of the research group. By means of these plants, wastewater (e.g.: olive mill and winery wastewaters, landfill leachate, sewage wastewaters, etc.) will be micro-phytotrophically treated and then analysed.

An ad hoc plant for the growth and the collection of microalgae in wastewaters will be studied and tested, reaching the goal to work in a full continuous mode. A pumping system, operating with variable flow rates, will be carefully developed to make the device less energy intensive and to reduce the hydraulic retention time. Downstream of the cultivation system, a plant will be designed for microalgal biomass settling, and the microalgal biomass will be collected using new methodologies, such as electro-coagulation.

Referent: Alessandro Alberto Casazza (alessandro.casazza@unige.it)

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Projects in reliability and safety of process plant engineering

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Projects in materials engineering

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***Thematic*: Materials Engineering**

Project: Electrode materials for reversible solid oxide cells

Keywords: solid oxide cells, electrode materials, electrolytes

Brief Description:
The main goal of this project is to study electrode and electrolyte materials for Solid Oxide Cells (SOCs) with mixed protonic and anionic conduction and operating at intermediate temperature (500-600°C).

Three are the key SOC's components: cathode, anode and a dense electrolyte, which contribute to main energy losses in the electrochemical process and their selection is critical for the optimization of the system.

The current materials for the air/oxygen electrode are perovskite-type conductive oxides, such La1−xSrxMnO3±d, La1−xSrxCo1−yFeyO3−d, for the fuel electrode a cermet of Ni/Yttria-stabilized Zirconia and for the electrolyte mainly stabilized zirconia or ceria (i.e. an oxygen anion conductor). Despite advances during last years, (HT)-SOCs still face a number of challenges, mostly due to their operating temperature, before reaching market readiness. In particular, poor dynamic behavior, modest tolerance to redox and thermal cycles, limited durability and poor tolerance to traces contaminants (sulphur, silicon etc).

Intermediate temperature (IT) operation (500-600°C) could reduce all these drawbacks. Especially, it will benefit the dynamic operation as required for coupling with renewable energies, and facilitate integration of the SOC with downstream exothermic processes for example the conversion of syngas into fuels.

The planned research will cover key aspects SOC devices such as electrodes and electrolyte microstructure and optimization of component manufacturing by advanced techniques. Accurate testing will allow for determination of intrinsic materials properties, inter-material compatibility, microstructure added value and performance.

Referent: Antonio Barbucci (barbucci@unige.it)

Link to the list of projects

***Thematic*: Materials engineering**

Project: development of novel catalytic material for conventional and unconventional heated reactors

Keywords: catalysis, unconventional heating, reactor engineering

Brief Description:
The development of unconventional heated reactors sets new challenges in the frame of the introduction of new reactor designs in the chemical industry, outlining a completely new approach for the chemical industry. The present project aimed at understanding the key parameters for the use of unconventional heating, studying and accounting for main process parameters, and investigating reactions and performances of chosen solutions in the frame of energy transition i.e., for H_2 production, or other relevant applications. The present project has an experimental nature and will focus on the development and design of engineered materials and processes, by focusing on performance assessment, mechanism, and kinetic investigations.

Referent: Gabriella Garbarino (gabriella.garbarino@unige.it)

Link to the list of projects

***Thematic*: Materials Engineering**

Project: Synthesis of graphene-composite multistructured spinel nanocatalysts for OER and HER in Anion Exchange Membrane Water Electrolysis

Keywords: Catalysts, Morphology, Spinel, Graphene, Oxygen Evolution Reaction (OER); Hydrogen Evolution Reaction (HER), AEM Water Electrolyzers , Electrochemical Impedance Spectroscopy (EIS)

Brief Description:
Anion Exchange Membrane (AEM) Water Electrolysis offers a sustainable and low-cost alternative to Proton Exchange Membrane (PEM) Water Electrolysis due to the possible use of transition metal based electrocatalysts instead of catalysts based on platinum groups metals (PGM) and to the lower cost of some other cell components, as stainless steel bipolar plates. Current research on AEMWE is mainly devoted to bring this technology to an advanced level of performance in terms of current density, catalysts activity, membrane duration and stability. Research on new materials is focused to improve OER in order to minimize energy loss at the anode due to the requirement of a four-electron transfer, and to keep high kinetics of HER also if not noble catalysts are adopted.

The proposed research activity will focus on the synthesis of different composite multi-structured nanocatalysts for both OER and HER and whose morphology will be optimized in order to improve both the electrochemical properties and the release of the formed gas bubbles. Moreover, the experimental activity will comprehend the analysis of the catalysts morphology and kinetics and their complete electrochemical analysis (EIS) at different scales: RDE, 3E tests and single-cell electrolyzers. Collaboration with companies producing materials and electrolyzers is envisaged.

Referent: Ombretta Paladino (paladino@unige.it)

Relevant links: https://it.linkedin.com/company/ecplab-unige
https://dicca.unige.it/laboratori/lab_chimica/ing_processi_chimici
https://www.ansaldoenergia.com/about-us/media-center/power-generation-news-insights/detail-news/ansaldo-green-tech-news-nemesi-project
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Figure: Tests of catalysts at ECPLab

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***Thematic*: Materials Engineering**

Project: Liquid infused surfaces for drag reduction

Keywords: superhydrophobic, liquid infused surfaces, wettability, drag reduction

Brief Description:
Fish and other aquatic species experience resistance when their body and the surrounding water are in relative motion. The release of mucus by fish allows to reduce such a drag force, because of the reduction in the velocity gradient (and thus in the shear stress) of the liquid near the surface, under both laminar and turbulent flow conditions. A similar layer of liquid lubricant could possibly be used to reduce the energy losses arising in the operation of ships or underwater vehicles. Recent advances in lubricant-releasing materials have seen the development of Slippery Liquid-Infused Porous Surfaces (SLIPS), porous scaffolds imbibed by a lubricant liquid stabilized by capillary forces.
Conceptually, SLIPS have many similarities to their conventional superhydrophobic (SHS) counterparts. They both rely on a lubricating layer, air or a liquid, to minimize the contact between droplets of water and the underlying solid surface or, alternatively, to maximize the slip velocity of a macroscopic liquid continuum flowing over it.
Not all questions have been answered, however, and the community still lacks clear design strategies for this energy-saving technologies. Aspects which are in particular need of work include the stability and the possible replenishment of the lubricant fluid, which tends to be washed away from the surface by the shear force exerted by the outer liquid, the choice of the (possibly hierarchical) micro- and nano-structure of the surface material, the choice of the lubricant, with bearings on viscosity ratios, capillary forces, affinity between the lubricant and the encasing scaffold material, etc.
The proposed doctoral project would integrate the production and the characterization of new SLIPS. These will be designed with new patterned structures to improve the liquid retention and prepared with facile methods to obtain a practical low cost, simple, scalable technique adaptable to the naval field.

Referent: Marina Delucchi, (marina.delucchi@unige.it)

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Projects in sustainability of products

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Thematics: **Sustainability of products**

Project: Circular hydrogen production from waste

Keywords: thermochemical processes, pilot plant, circular economy

Brief Description:
The decarbonization of the European and global energy systems requires the development of effective energy carriers that can complement electrification in specific high energy density applications. In this space, renewable hydrogen is attributed a crucial role, although the replacement of the current 120 million tonnes global annual demand requires a major effort in the development of a spectrum of technologies.

Gasification represents a pathway to hydrogen with great potential, as it can couple the production of a renewable vector with the conversion of large flows of waste, in a circular approach. In this project, we propose the design and demonstration of an integrated process for hydrogen production from textile waste and biomass through pyrolysis-gasification, where biochar as a by-product finds an application as an adsorbent in the purification of hydrogen itself.

In specific, we will upgrade and validate a 0.5 MWth spouted bed oxygen-steam gasifier fed with biomass and textile waste and optimize its operation for hydrogen production through an extensive experimental campaign based on detailed process modelling activities. Moreover, we will recover the biochar produced during gasification and treat it in a fixed bed reactor to activate it for use as an adsorbent in substitution to commercial activated carbon in a pressure swing adsorption unit. The adsorption unit's efficiency in separating hydrogen will be tested on an artificial syngas stream replicating the average gas composition obtained in the spouted bed to determine the hydrogen purity and recovery rates attainable in comparison with a commercial product. In addition, purified syngas with specific gas composition could also be converted into chemicals through synthesis catalytic reactions to produce methanol (ratio $H_2/CO=2$), ammonia (gas-phase catalytic reaction) or Fischer-Tropsch liquids as naphtha, diesel and gasoline (ratio $H_2/CO=0.6-2$), showing the high versatility of the system.

The project will demonstrate the efficiency and feasibility of a closed-cycle process where hydrogen can be generated from waste and renewable biomass, and its purification can be achieved with the use of a pre-treated by-product generated within the same process. The research efforts accomplished will contribute towards the development of circular hydrogen technologies on the Italian territory and towards enhancing the country's competitiveness in energy innovation through dissemination to fellow academic and research institutions as well as key industrial actors.

Referent: Elisabetta Arato (elisabetta.arato@unige.it),
Cristina Moliner (cristina.moliner@unige.it)

Link to the list of projects

Thematic: **Sustainability of products**

Project: Molten Carbonate Fuel Cells applied to energy transition

Keywords: energy transition, molten carbonate fuel cells, gas to power, power to gas, experimentation and modelling

Brief Description:
In the current context of energy transition, molten carbonate fuel cells (MCFCs) are proposed as a strategic solution that allows the production of energy with high efficiency and the simultaneous capture of CO_2 from the exhaust of existing plants.
In this context, UNIGE, and specifically the Department of Civil, Chemical and Environmental Engineering - DICCA, has developed a internationally recognized methodological approach for the multiscale analysis of MCFCs, from the study of the electrode microstructure to the process analysis of plants, based on the parallel proceeding of modelling and experimentation.
The proposed doctoral project would integrate into this scenario by offering the possibility of a research activity that aims to promote the development of MCFC technology in a perspective not only of scientific investigation, but also of industrial production.
Attention would be focused on the production of innovative components to be tested in small-sized single cells, combining the tests with an appropriate theoretical analysis, aimed at understanding the phenomena involved to optimize electrochemical performance.
It is expected that the work, both experimental and simulation, will be carried out mainly at the CapLab, joint laboratory between the DICCA department and the Ecospray Technologies company.

Referent: Barbara Bosio (barbara.bosio@unige.it)

Relevant links: https://vimeo.com/850098889

Link to the list of projects

Thematic*: *Projects in sustainability of products

Project: Medium-low temperature pyrolysis of biomass to produce chemicals and biofuels

Keywords: Thermal cracking, biomass characterization, exhausted biomass, biofuel production.

Brief Description:

In the last years, considerable efforts have been made to find new solutions for replacing fossil raw materials with renewable sources. The main reason behind these efforts lies in the need to reduce greenhouse gas emissions and in the production of non-fossil origin biofuels and chemical intermediates.

After the recovery of compounds of interest, microalgae and different types of biomasses can be further treated by pyrolysis at medium-low temperature (300-600 °C).

Indeed, the thermal cracking of macromolecules in the biomass can lead to the production of liquid and gaseous products. Depending on the operating conditions or on the kind of biomass used, such products can find application as alternative biofuels.

At the same time, the possibility of obtaining chemical intermediates of interest for the industrial sector will be investigated.

The topics of research will cover the study of different matrices to be tested, the evaluation and optimization of the pyrolysis conditions (temperature, time, etc.), the development of analytical methods for a complete characterization of the liquid, gaseous and solid products.

The possibility of obtaining new products from biomasses and exhausted biomasses fully places this activity in the trend of green chemistry.

Referent: Alessandro Alberto Casazza (alessandro.casazza@unige.it)

Link to the list of projects

***Thematic*: Sustainability of products**

Project: Development of green chemistry technologies and processes for the valorization of waste or bio-derived resources

Keywords: catalysis, reactor engineering, biomass conversion, high value-added products

Brief Description:
Industrial chemistry is seeking new catalysts for the development of "green" processes arising from renewables and by maximizing renewable resources. In this frame, the production of green and bio-hydrogen, chemical commodities or pseudo-commodities is focusing the attention of scientific research by also addressing important challenges from material and reactor points of view. Together with H_2, the production of aldehydes, dienes, solvents, and emulsifiers could be foreseen starting from renewables (biomass, bioethanol etc.) or through unconventional processes. This doctoral project involves the development of processes, technologies, and catalytic materials for the conversion of organic molecules to products of industrial interest with a focus on green industrial chemistry and energy transition. The present project has an experimental nature and will focus on the development and design of engineered materials and processes in the frame of green industrial chemistry by focusing on performance assessment, mechanism, and kinetic investigations.

Referent: Gabriella Garbarino (gabriella.garbarino@unige.it)

Link to the list of projects

***Thematic*: Sustainability of products**

Project: A Sustainable Process for the production of Electrodes for AEM /ALK electrolyzers and validation of electrode performance in single-cell test bench

Keywords: Electrodes, Sustainable process, Anion Exchange Membrane (AEM) Electrolyzers, Alkaline Electrolyzers, test-bench, single-cells, stability, duration, Electrochemical Impedance Spectroscopy (EIS).

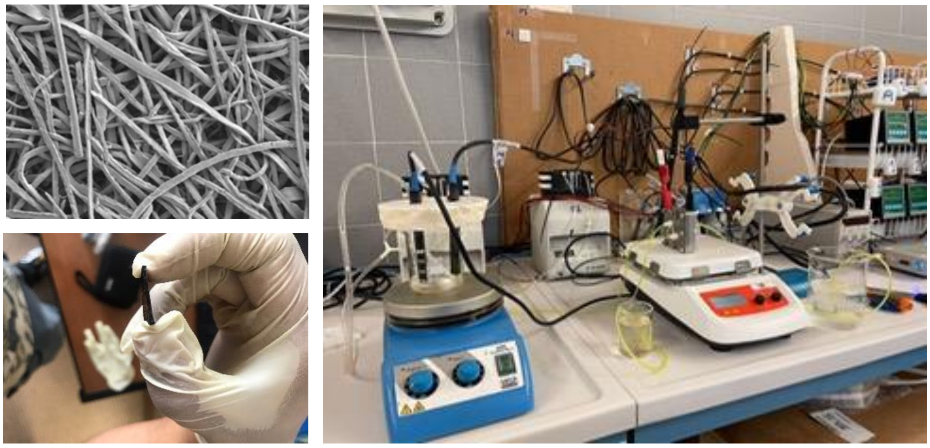
Brief Description:
Electrochemical conversion and energy storage systems such as electrolyzers, fuel cells, and redox flow batteries address the intermittency of energy sources like solar, wind, and wave power. Actual research worldwide is manly devoted to develop new materials for improving the performances of these electrochemical reactors. In the last few years, research in DICCA-ECPLab has been dedicated to the development of a new sustainable process for depositing nanocatalysts on OER and HER electrodes (a patent has recently been filed) without managing powders.

The proposed research activity will focus on: 1) the optimization of the fully automated process, designing stages and units, in order to avoid any contact with the reactants; and 2) optimizing the operating conditions of the new deposition process, to improve the electrochemical and transport properties of the electrode and to increase its stability and duration. The experimental activity will consist in both the production of the new electrodes inside the lab-scale production plant and in the evaluation of the electrochemical performance of the products as components of single-cell (5cm2, 25cm2) electrolyzers. The experimental data will be used to tune an already existing digital twin of the single-cell AEM electrolyzer. Collaboration with industry is envisaged.

Referent: Ombretta Paladino (paladino@unige.it)

Relevant links: https://it.linkedin.com/company/ecplab-unige
https://dicca.unige.it/laboratori/lab_chimica/ing_processi_chimici
https://www.ansaldoenergia.com/about-us/media-center/power-generation-news-insights/detail-news/ansaldo-green-tech-news-nemesi-project

Figure: Electrode and test-bench at ECPLab



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Chemical processes with reduced environmental impact

Project: CO_2 to use: catalytic processes design and investigation

Project: Circular hydrogen production from waste

Project: Molten Carbonate Fuel Cells applied to energy transition

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***Thematic*: Chemical processes with reduced environmental impact**

Project: CO_2 to use: catalytic processes design and investigation

Keywords: CO_2, e-fuels, CO_2 utilization, chemical reaction engineering, catalysis

Brief Description:
CO_2 use is becoming as one of the key-challenges for the next future and the development of new technologies and processes is pivotal to achieve sustainable development goals, set out by the United Nations, and achieving carbon neutrality by 2050. The PhD project proposed here will be focused on catalysis and chemical reaction engineering in the development of new processes for this application by aiming at the reduction of environmental impact and by possibly outlining new technological solutions and by looking at the process, reaction mechanism of chosen reactions and kinetics to produce e-fuels and e-chemical. Of utmost importance will be the coupling with renewable resources. An experimental point of view will address the present project.

Referent: Gabriella Garbarino (gabriella.garbarino@unige.it)

Link to the list of projects

***Thematic*: Chemical processes with reduced environmental impact**

Project: Circular hydrogen production from waste

Keywords: thermochemical processes, pilot plant, circular economy

Brief Description:
The decarbonization of the European and global energy systems requires the development of effective energy carriers that can complement electrification in specific high energy density applications. In this space, renewable hydrogen is attributed a crucial role, although the replacement of the current 120 million tonnes global annual demand requires a major effort in the development of a spectrum of technologies.

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Referent: Elisabetta Arato (elisabetta.arato@unige.it),
Cristina Moliner (cristina.moliner@unige.it)

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Referent: Barbara Bosio (barbara.bosio@unige.it)

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Others Projects

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