SINCHEM PhD subject

Aqueous-phase reforming of the non-lipid fraction of micro-algae exploitation”
(acronym: APHARMAE)

HOME INSTITUTION: Politecnico di Torino. Supervisors of the PhD student in Torino: Proff. Raffaele Pirone and Samir Bensaid (DISAT - DIpartimento di Scienza Applicata e Tecnologia, raffaele.pirone@polito.it)

HOST INSTITUTION 1: Ecole Nationale Supérieure de Chimie de Montpellier (ENSCM). Supervisor of the PhD student in Montpellier: Dr. Francesco Di Renzo (direnzo@enscm.fr, www.macs.icgm.fr)

HOST INSTITUTION 2: to be defined

The "Roadmap for moving to a low-carbon economy in 2050" (COM (2011) 112) outlines the key points on which the action promoted by the European Union should be built in order to assist the transition from an oil-based economy to a lower carbon emissions one by 2050. The analysis carried out by the European Commission reveals that CO_2 emissions could be almost totally eliminated by 2050 and that it is possible to partially replace fossil fuels in the energy sector (transport and fuels). To achieve these goals, it is necessary to develop energy efficient technologies that can provide low CO_2 emissions processes, also through the use of renewable sources. This requires the use of CO_2 as a carbon source and the exploitation of biomasses, especially the most efficient ones and belonging to the third generation, such as micro algae.

However, the use of microalgae exhibits high costs for industrial-scale application, in particular for downstream processing to obtain biofuels. More than 40% of the total cost for oil production from microalgae is related to drying/concentration of the algal mass, treatments required upstream the thermo-mechanical breaking of the cell wall for the lipid fraction extraction. The obtained lipid fraction can be converted into fruitful products (equivalent to fossil diesel), but one key point could paradoxically be the exploitation of the non-lipid fraction, that is currently unused and can significantly improve the economics of the overall process, through the production of H_2 to be used in the hydrogenation/selective cracking stages of the bio-refinery. Efficient valorisation of residual biomass is indeed a general problem for all second and third generation biomass processes and the algal biomass presents a significant asset in the virtual lack of lignin in its residual byproducts.

The aim of this doctorate project is to study the process of APR (aqueous phase reforming) of the non-lipid fraction from microalgae processing in order to extend such a “new” reforming technology to substrates never tested (proteins) or compounds (such as complex polysaccharides) that up to now gives the worse performance in the APR process. It is especially interesting to evaluate the comparative economics of the complete transformation of residual algal biomass to H_2 and light gases towards the economics of processes of selective degradation allowing to form valuable specialty chemicals from the algal biomass.

Important selectivity challenges govern the production of H_2 by APR, because the mixture of H_2 and CO_2 formed in the process is thermodynamically unstable at low temperatures with respect to the formation of methane or higher alkanes with a difficult control of the reaction selectivity. Accordingly, the selective formation of H_2 represents a classic problem in heterogeneous catalysis and reaction engineering: the identification of catalysts and the design of reactors to maximize the yields of desired (intermediate) products at the expense of undesired byproducts formed in series and/or parallel reaction pathways. In principle, the hydrogen selectivity can be controlled by altering the nature of catalytically active metal and metal-alloy components, and by choice of catalyst support. Moreover, the feed concentration of oxygenated hydrocarbons in the aqueous solution should play an important role in the reforming process too.

The research program aims to study the dependence of several parameters on the APR of diluted biomass mixtures, initially constituted by sugars and amino acids. Catalysts will be prepared, characterized and tested in the APR process, and XRD, XPS, BET surface area, ICP-AES, H_2 and CO-chemisorption, TPR and TPD will be involved to characterize the active surface. The investigation will also aim to develop a reactor configuration that optimize the yield of hydrogen and other valuable products by modeling the kinetic of consecutive reactions, being the final goal of the work the increase of productivity of desired compounds. The PhD student will be able to improve his/her expertise in elaboration of dispersed materials, bulk and surface characterization techniques, and catalysis engineering of heterogeneous processes. He/she is expected to spend 21 months in the home institution, 12 months in the guest institution 1 and 3 months in the guest institution 3.