Project 3.5 Nanoengineering of multicomponent metal-free carbonaceous materials for biooil upgrading through ultrasound-assisted selective redox photo-catalysis in continuous-flow reactors

Supervisor: dr hab. inż. Juan Carlos Colmenares Q.
Institute: of Physical Chemistry
Unit: Group 28: "Catalysis for sustainable energy production and environmental protection, CatSEE"
www: https://photo-catalysis.org

Background:

Climate change mitigation has become the focus of incoming worldwide initiatives and policies with the first and foremost mission of disrupting the strong reliance of our society on fossil fuels to guarantee sustainable development. Establishing a biorefinery model capable of feeding the entire industry with the key bulk and fine carbon-based chemicals that otherwise rely on petrochemical processes is the cornerstone for this technological transition. Lignocellulosic and sea-food-based organic wastes have been recognized early on as the ideal feedstock not only for being the largest renewable source of carbon not competing with food reserves but also for its unique chemical composition; being made up of a nitrogen-containing polysacharide-based fraction (chitosan derived from partial deacetylation of chitin which is coming from the sea-food waste) and sulphur-containing complex aromatic polymer (e.g., Kraft lignin), such biomass could potentially give access to an immense portfolio of key molecules and materials. Currently, only the carbohydrate fraction is effectively used in lignocellulosic biorefineries, while a large side-stream of lignin (technical lignin) is discarded in the process by delignification treatments, serving at most as a low-grade fuel or low-value resins and lubricants given the lack of effective valorization routes for this component. From the side of chitin, which is a straight-chain biopolymer, it is also an underutilized resource due to its inherent insolubility in common (organic) solvents and the expensive and wasteful methods employed for the extraction of chemicals from it. This proposed project has the potential of strong influence on the field of green and sustainable materials synthesis and processes, renewable energies, and chemicals production from organic wastes. Therefore, the final outcome of the proposal will lead to profound benefits to humanity in the long term. These pioneering studies will permit us to understand and optimize (a) the synergistic effect of combining ultrasound with hydro(solvo)thermal, and thus (b) predict carbon-based photocatalyst performances manipulated by the full control of ultrasound effects during the selective oxidation and C-C reductive coupling of bio-oil-based molecules, what will result in (c) activity/selectivity/stability improvement of promising metal-free carbon-based photocatalysts working thanks to light utilization and sonication which open the possibilities for better ways of management and valorization of lignin- and chitin-containing organic wastes. The uniqueness of this project rests on a combined approach of understanding/design/synthesis of effective metal-free carbon-based photocatalysts with optimized composition capable of working under optimized continuous flow sonophotocatalytic conditions for the valorization of bio-oil-based model compounds..

Aim:

The goal of this project is the synthesis of multicomponent metal-free carbonaceous photocatalysts, the study of their activity/selectivity in the selective photo-oxidation and C-C reductive coupling of bio-oil-based model molecules, and the correlation of their performances with the composition, surface morphology, and distribution of the active sites. Particular emphasis will be placed on: a) new procedures for the synthesis of metal-free N-/S-containing carbon-based photocatalysts using ultrasound-assisted hydro(solvo)thermal method, b) the use of very abundant organic wastes (chitosan and lignin) as the natural sources of C/O/N/S for materials preparation, c)

the study of the mechanistic aspects of flow ultrasound-assisted photocatalytic method for the selective oxidation and C-C coupling of bio-oil-based model molecules and the study of photocatalysts performances under such specific continuous flow sonophotocatalytic environment. This project's proposed materials will be a multicomponent carbon-based composite prepared from commercial chitosan (precursor of C, N, O) and lignin (precursor of C, S, O, aromaticity). Systematic basic research of the effect of green and unconventional source of ultrasonic energy (e.g., effective mass transfer, microstreaming, cross-linked radical polymerization, etc, effects often inaccessible through conventional methods) on the formation of active composite for selective redox photocatalysis. We hypothesize that obtained composite materials will be characterized by special redox photocatalytic properties thanks to the specific and extraordinary features of their elements (carbon matrix self-doped by N/S/O), especially when their synthesis can be improved by the pre-treatment with ultrasounds at ambient conditions before hydro(solvo)thermal HST (synergistic effect of two solvents) procedure. Chitosan and lignin will react during sonication in different ways, which will promote a better crosslinking between them, and thanks to that, we will obtain a versatile multicomponent feedstock for the hydro(solvo)thermal method, thus reducing the temperature and time of HST. That obtained materials will differ in physicochemical and photocatalytic properties under visible light, which will have a positive effect on bio-oil-based model molecules valorization through continuous flow sonophotocatalysis..

Requirements:

- Expertise sought from a Ph.D. student: Graduates of chemistry, physics, materials science, and related university faculties, holding a Master of Science or equivalent degree (obtained recently, approx. < 3 years before starting this project) with an aptitude and passion for natural and exact sciences, with good knowledge of English and outstanding motivation and open mind for interdisciplinary research at the border of chemistry-physics are invited to join this project research group.

Additionally:

- CV
- copy of MSc diploma
- distinctions granted by virtue of scientific research, grants, awards and scientific experience acquired outside your own research work place in the country or abroad; participation in workshops and scientific trainings; participation in research projects.
- experience in conducting scientific research in the field of catalysis, organic synthesis and materials characterization.
- at least the opinions of two independent research scientists, specialists in the field of chemistry and related sciences.
- very welcome are publications in reputable publishing houses / scientific journals.