1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: *Nature-inspired hydrophobic-hydrophilic separation materials*

1.1 Project goals

The goal of the project is to prepare hydrophobic-hydrophilic separation materials inspired by nature (e.g. lotus and petal effects; biomimicry of Namib Desert beetle surface or spider silk) and to use compounds derived from the natural sources. Depending on the final application the material can be either solely (super)hydrophobic or (super)hydrophilic as well as can possess dual-features, e.g. macroscopically hydrophobic with hydrophilic domains in microscale. An important part is the material modification that can be accomplished by physical structuring, chemical modification or combination of both techniques. The aim of the modification is to control surface wettability and material properties (physiochemistry, mechanical features). Finally, the generated membranes will be used in the separation processes, e.g. separation of oil-in-water emulsions, water purification by membrane distillation and filtration, including the controlling of fouling properties.

1.2. Outline

The progress of advanced materials based on mixed organic and inorganic species starts to be one of the most ground-breaking research areas. Integrating hybrid materials enables the tailoring of properties ranging from the atomic to the macroscopic scales to tune the final physical and chemical properties. Evolution in this design, have a substantial influence on different areas, including separation techniques, smart coatings, polymer composites, and biomedical application. Recently, water pollution and scarcity become to be a real problem across the globe where hybrid materials were also have been employed to overcome. In nature, there are many mechanisms to harvest water by the utilization of materials with a unique design. Spider silk, with microscopic structures having periodic joints on their surface, presenting an exceptional capability for collecting tiny water drops. The Namib Desert beetle (*Stenocara gracilipes*) that can collect water from air by its rugged back implementing hydrophilic bumps across flat hydrophobic waxy regions. Several biomimetic membranes were inspired by this technique for application including water harvesting, and water-oil separation. The membrane modification can be done also by the utilization of compounds derived from the natural sources, e.g. cinnamic, myristic, and tannic acids. Cinnamic and myristic have the sources in cinnamon and nutmeg, respectively. These compounds can be efficiently used as natural modifiers to generate superhydrophobic surfaces and to reduce the utilization of toxic and corrosive perfluorinated silanes modifiers. An application of natural biopolymer i.e. chitosan that is consider as a biowaste enables to tune the surface properties of the material by controlling wettability and fouling. The treatment of hydrophobic surface by chitosan and tannic acid gives a combination of physical and chemical modification by formation of hierarchical layer-colloidal nanosphere. Resulting in turning of hydrophobic character to superhydrophilic one. In the course of the project it is foreseen to produce different type of the separation material and to introduce surface modification step for controlling wettability and other features.

1.3. Work plan

- preparation of the porous polymeric membranes from hydrophobic material, e.g. polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE) or polypropylene (PP),
- modification of the membrane material by changing the chemical composition and/or physical structure (e.g. pattering, roughness tuning) – utilization methods inspired by nature (lotus and petal effects; biomimicry of Namib Desert beetle surface or spider silk both for water harvesting)
- material characterization with the implementation of various analytical methods, e.g. microscopic, spectroscopic techniques,
- membrane tests in the separation processes, e.g. membrane distillation, filtration,
- description of material features and correlation with the transport and separation efficiency.

1.4. Literature

1. S. Wang, K. Liu, X. Yao, L. Jiang, Chemical Review 115, 16 (2015) 8230-8293
2. M. Liu, S. Wang, L. Jiang, Nature Reviews Materials 2, (2017) 17036
3. J. Kujawa, W. Kujawski, S. Cerneaux, G. Li, S. Al-Gharabli, Journal of Membrane Science, 596 (2020) 117597
4. J. Kujawa, Journal of Membrane Science 580 (2019) 296-306
5. J. Kujawa, S. Al-Gharabli, W. Kujawski, K. Knozowska, ACS Applied Material and Interfaces, 9 (2017) 6571-6590
6. S. Al-Gharabli, W. Kujawski, H. A. Arafat, J. Kujawa, Journal of Membrane Science 541 (2017) 567-579
7. J. Kujawa, S.Cerneaux, W. Kujawski, M. Bryjak, J. Kujawski, ACS Applied Material Interfaces, 8 (2016) 7565-7577

1.5. Required initial knowledge and skills of the PhD candidate

- Basic knowledge in the field of membrane separation techniques, membrane formation and modification
- Basic knowledge in the analytical techniques used for membrane characterization, SEM, AFM, DSC, porosimetry
- The ability to cooperate in a team, also in international one

1.6. Expected development of the PhD candidate's knowledge and skills

- The ability to analytical thinking
- Keen to learn new techniques and instrumentations
- Eager to work hard and contribute to the success of the project
- Be interested in interdisciplinary science fields from the borderline of material chemistry, membranes, and separation technologies