Abstract for General Public

Title: Hierarchical carbons with in-pore adsorbed redox-active species as flow electrodes for batteries and hybrid energy storage (NoCrossover)

Electrode materials play a vital role in designing sustainable energy storage devices with improved performance. The ever-growing market demand combined with the economic and ecological compatibility has driven enormous research work in the field of electrochemical technologies. Redox flow electrodes (REFs) are promising for grid-scale energy storage applications; however, they should be less toxic and inexpensive, which requires new electrode designs. On the other hand, the development of RFEs is hampered by the shuttling of redox species under the applied potential that requires implementing of expensive membranes. High surface area carbons can serve as carrier for redox-active species to produce electrodes in slurry-form with low risk of shuttling and for large-scale stationary flow batteries as well as hybrid flow cells. RFEs using nanoporous carbons possess renewables surface and undergo passivation at reacting sites and the distribution of charges is nearly uniform within the porous carbon particles owing to the access of electrolyte from multiple sites. Nevertheless, random carbon porosity favors uneven distribution of redox species, some vacant pores and leaves reactive edge sites which are prone to develop undesired surface functional groups. In fact, most of the commercial carbons offer random pores and only a few are available with hierarchical and unique pores, however, they are very expensive (a few grams cost hundreds of dollars).

This project is aimed at developing low-cost templated carbons with hierarchical porosity from commonly available chemicals which will possess unique pore sizes and low surface functional groups. These characteristics combined with optimal sp^2/sp^3 carbon ratio greatly improve charge transfer properties of carbon materials and promote chemical bonding of redox species in the pores. These hierarchical carbons will be then used as host materials for anchoring of redox couples e.g., anthraquinone (AQ/AQ^{2-}), iodine and 2,2,6,6-tetramethylpiperidine N-oxyl ($TEMPO/TEMPO^+$) and to prepare electrodes in slurry state in low-cost water-in-choline salt electrolyte (~2€/kg) for flow batteries and hybrid energy storage cells. The use of carbons with hierarchical pores enable to effectively adsorb the selected redox species which then can participate in redox reaction during long-term charge/discharge of flow electrodes. To do that, at first, carbons with unique sp^2/sp^3 ratio and evenly distributed pore structures will be synthesized by using aluminum citrate or magnesium citrate as precursor materials. In addition, D-Glucose will be used as carbon precursor with silica nanoparticles of various sizes as template. Chemical and electrochemical routes will be used to further modify structural parameters of carbons and to anchor redox species onto their surface and to adsorb within the pores. Physicochemical techniques such as in-situ Raman spectroscopy, X-ray photoelectron spectroscopy, electrochemical impedance spectroscopy and electron microscopy (SEM, TEM) will be used to determine the influence of charge transfer on structural parameters of hierarchical carbons and the behavior of solvent and ionic species in the pores. Charging mechanisms of RFEs, effects of activation and concentration overpotentials, the electrolyte concentration and flow rates on electrochemical performance in full cells will be investigated. The shuttling of redox species will be further suppressed by using high conductivity water-in-choline salt electrolyte.

Overall, this project aims at **i)** synthesizing of carbons with hierarchical pores, chemical bonding of the redox species onto carbon surface and in the pores, and developing RFEs slurry in water-in-choline nitrate electrolyte, **ii)** understanding the charge transfer mechanisms toward and from carbon material, and **iii)** implementing these RFEs in flow batteries and hybrid flow capacitor cells. The project applicant together with co-worker, PhD students and in collaboration with researchers from Poland and Austria will carry out planned tasks. The project leader is confident of training young team members as emerging scientists and developing infrastructure at Poznan University of Technology for investigating the reaction mechanisms, novel materials and energy storage devices in *NoCrossover* project.