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Effect of the structural disorder in carbon material on capacitive and faradaic charge storage

The project concerns efficient charge storage at the electrode/electrolyte interface. Carbon materials with a porous structure will be used as electrode materials. For the preparation of carbon materials with controlled porosity, it is planned to use the replica technique. The role of the template (matrix) will be realized by an alkali metal salt, such as sodium chloride or magnesium oxide. On the other hand, the carbon precursor will be a polymer, such as phenolic resin or polyvinyl alcohol. The preparation conditions of the carbon materials (temperature, type of precursor, matrix, molar ratio) will allow obtaining a series of materials with different degrees of order. Water or hydrochloric acid will be used to remove the template (while other matrices use unfriendly hydrofluoric acid).

The goal of the project is to determine the effect of ordering, defects, the presence of radicals and active sites in the structure of the carbon material on the ability of the electrode to efficiently store charge. The possibility of long-term cyclic operation of the electrochemical system will also be investigated. Aqueous salt solutions as well as organic media will be used as the electrolyte.

Parameters of carbon materials determining the extent of their defects, the presence of active sites and radicals will be determined by spectroscopic methods (Raman spectroscopy, electron paramagnetic resonance spectroscopy), and then correlated with the capacity of electrodes in different charging/discharging modes.

To extend the cycle life of electrodes, the priority will be to modify the composition of the electrode/electrolyte interface through the use of eutectic solutions, or supersaturated solutions that allow the limiting of water molecules presence at the interface and reducing corrosion of the current collector.

The hybridization of electrostatic and faradaic processes, involving both the electrolyte solution and the electrode, will contribute to a significant increase in the stored charge, in turn energy, of the electrochemical system.

Advanced techniques with application of electrochemical quartz microbalance and electrochemical dilatometer will be used to study in detail the mechanism of processes occurring at the electrode/electrolyte interface. The former method will determine the flow/sorption of ions on the electrode during polarization, while the latter will determine the volume changes of the electrode during polarization.

Modeling with novel computer programs will contribute to the determination of the size of molecules, ions, type of bonding and interactions at the electrolyte/electrode interface, which will allow the determination of ion hydration, estimation of intra/interaction energies in the electrolyte, and enable better elucidation of the mechanism of charge accumulation on the electrode.