Today the major concern of almost all scientific community goes towards making a world a better place for future generations. In order to make it possible researchers are looking for improvement of existing as well as new technologies and processes which are more friendly to the environment. In recent years a huge increase of interest in renewable sources of energy like wind or solar one was observed. Although they have several advantages, they induced serious problem with unequal power distribution. Briefly, in case of solar panels the most of energy is generated during the day when the energy demand is the lowest, hence, the question is how to deal with all this 'extra' energy. For this purpose there is a need of sustainable and cheap systems for energy storage. One of the possibilities to solve this problem is exploitation of electrochemical capacitors in order to accumulate all extra energy and release it on demand. Electrochemical capacitors, called often supercapacitors or ultracapacitors are electrochemical devices storing energy by ion organization in electrical double-layer, formed at the electrode/electrolyte interface. Because of fast electrostatic nature of ion attraction, the power rates for supercapacitors are excellent, however, they suffer from moderate energy density. Hence, their use is limited to the systems which require a lot of energy in a very short time (to start the car engine, to elevate the lift or the load in crane). On the other hand, the main disadvantage of current supercapacitor technology is application of volatile organic solvents for electrolytes and high cost of Wh/kg. To make this technology more accessible and safe, a lot of interest was put on capacitors operating in aqueous electrolytes; such a electrolytic solution is considered as cheap and environmental friendly.

Apart from sustainability and environment-related issues, the most interesting feature of capacitors operating in aqueous medium is so called pseudocapacitive effect, which is related to fast and reversible redox reactions, mainly at or on the electrode surface. Hydrogen electrosorption and after oxidation process on surface of the electrode may be considered as one of such phenomena and thus is a source of extra energy in supercapacitors. However, in order to make this 'technology' more available and to improve the performance of the devices exploiting hydrogen storage process, a better understanding of principles and phenomena occurring in this systems is needed.

The main aim of this project is the examination of hydrogen storage phenomena in water, gel and hydrogel electrolytes based on inorganic salts solutions in so called hybrid redox system. Term 'hybrid redox system' refers to electrochemical cell with porous carbon electrode and electrolyte where at the interface both capacitive and redox processes are occur. The capacitive process is considered as fast charging/discharging of electrical double-layer at the surface of the porous electrode; by 'redox' one may consider in this particular case cathodic reduction of water and hydrogen sorption in statu nascendi in pores of the carbon electrode.

Hydrogen evolution and electrosorption from aqueous medium is however well described in the literature for strongly acidic and alkaline medium. At the moment, to our best knowledge there is no comprehensive work concerning hydrogen electrosorption from neutral medium as well as and from gel and hydrogel electrolytes.

The principle of hydrogen storage phenomena is connected with electrochemical stability of water limited to voltage value 1.23V; at such voltage oxygen is generated at positive electrode while hydrogen on negative one. Therefore, this voltage value is the limit for all electrochemical systems operating in water-based electrolytes; if this value is exceeded, redox activity of the system is focused only on hydrogen or oxygen evolution reactions and no other reactions are theoretically possible.

The potential of hydrogen evolution might be calculated according to formula:

$$EH2 = -0.059*pH \qquad (1)$$

As discussed above, after exceeding the voltage of water stability, one should expect immediate decomposition of water leading to hydrogen and oxygen evolution. However, it has been found that in presence of highly microporous carbon materials it is possible to shift the potential of hydrogen evolution of 300mV towards more cathodic values; such a shift is possible presumably because of hydrogen electrosorption phenomena in pores of carbon materials. It means that during decomposition of water, generated hydrogen ad-atom are firstly 'captured' and adsorbed on the surface of carbon electrode and have no possibility to recombine and evacuate from the system. Thus, with the overpotential foe hydrogen evolution, the theoretical effective electrochemical window of water-based system can be extended up to 1.53V.

Additionally, according to the reaction below,

$$C + x\ H2O + x\ e- \leftrightarrow <CHx> + x\ OH – \qquad (2)$$

hydrogen electrosorption is an electrochemical reaction where the charge is transferred between reacting species, so it can be considered as a source of additional charge, called pseudocapacitance.

For this examination several neutral solutions of inorganic salts i.e. nitrates, sulfates and sulfites of alkali metals will be examined as potential electrolytes for hydrogen sorption. The driving force for this examination is the fact that the composition of the salt has a major impact on fundamental properties of the electrolyte like pH value, ionic strength, conductivity and ion solvation shell.

The research will be carried out by in situ and ex situ methods. Firstly, physicochemical characterization of electrode material will be performed in order to estimate their specific surface area. A proton binding curves estimated by potentiometric titration in a solution of known ionic strength are also scheduled to be done. Additionally, thermograms of electrode before and after electrochemical examination will be done with by thermogravimetric analysis combined with mass spectroscopy. This research allow determination of electrode oxidation and change of the surface functional groups.

A structural properties of carbon electrode materials will also be determined by Raman spectroscopy. An estimation of electrochemical properties will be done by three fundamental electrochemical methods i.e. galvanostatic charge/discharge, cyclic voltammetry and electrochemical impedance spectroscopy in wide range of frequencies (100kHz – 1mHz). Electrochemical experiments will be carried out in two and three electrode cell configuration.

The results obtained from this study appear to be of great importance, with cognitive and developing factors to the knowledge and understanding of phenomena occurring at the electrode/electrolyte interface and may allow more efficient design and exploitation of energy storage systems.