Nowadays, with rapidly growing energy demand, there is an increasing interest in improving electrochemical storage systems acting as independent power supply units but also as supporting systems e.g. for renewable energy sources. In addition, the rapid development of hybrid and electric vehicles technology requires power and energy-efficient, stable, cost-effective and environmentally friendly energy systems. Electrochemical capacitors, also known as supercapacitors, are devices capable of storing a large amount of electrical charge and ultrafast release of stored energy, i.e. characterized by very high power density. In their design, we can distinguish three main elements – two electrodes, separator and electrolyte. In the simplest approach, the electric charge is accumulated in an electrical double-layer, which upon applying of external voltage, forms at electrode/electrolyte interface. Although supercapacitors are systems characterized by high power, unattainable for conventional chemical energy sources, the density of stored energy still remains lower than in the case of batteries. Therefore, these supercapacitors are mainly used as systems supporting chemical sources operating at high current densities, and less often as independent energy storage units. However, due to the fact that there are no chemical changes during their operation, they also exhibit very high stability, i.e. a negligible loss of properties during repeated charging/discharging cycles.

In terms of electrode materials, activated carbons are most commonly used. That is due to their chemical and thermal stability, the wide availability of precursors and ability to adapt their structural properties to required applications. They also exhibit a high specific surface area (> 1000 m^2 g^{-1}) and a pore volume (> 0.5 cm^3 g^{-1}) which ensures the possibility of storage of incomparably greater electrical charge on their surface than electrodes of conventional capacitors. Another important issue is the selection of proper electrolyte. Commercially, organic electrolytes are most commonly used due to the wide potential window, and as a consequence, higher energy density. However, they are toxic, flammable and expensive, in opposite to aqueous electrolytes, i.e. much safer, less expensive and positively affecting the charging/discharging dynamics of supercapacitor due to their high ionic conductivity. A key element of the supercapacitors design is also a separator, physically separating the electrodes and ensuring the electron transfer only through an external circuit.

In this project, we propose research aimed at the development of new separators, which in addition to the physical barrier, will also act as ion-conducting membranes serving as a reservoir for the electrolyte which will allow the reduction of the volume of introduced solution, affecting the final weight of the device and potential production costs. The main component of the membranes, or more precisely gel polymer electrolytes, will be cellulose, i.e. a biopolymer which because of its wide availability, biodegradability and low cost seem to be a promising material for application in supercapacitors. Also, the membranes will be produced from a sodium hydroxide/urea mixture, i.e. without the use of any toxic organic solvents and complicated multi-step fabrication procedures. Their structure will be determined using a wide spectrum of physicochemical and electrochemical techniques.

The applicability of membranes in supercapacitor will be tested in aqueous solutions, e.g. in sulfuric acid, but also with the use of polyoxometalates, i.e. mixed-valence inorganic compounds which according to our research are a promising alternative option, while being more environmentally friendly. The supercapacitors will undergo a series of electrochemical tests, based on which major electrical parameters of supercapacitors, i.e. capacitance, energy, power and stability during long-term cyclic operation will be determined. It is expected that the designed systems will be characterized by capacitive properties comparable with their analogues using conventional separators, e.g. polypropylene and excess of liquid electrolyte.