Biopolymer-based components for electrochemical capacitor

The main objective of the project is to design the preparation method of gel polymer electrolytes and electrode materials based on biopolymers, cellulose or chitin, and to electrochemically characterize obtained materials as possible components for electrochemical energy storage devices.

Cellulose and chitin are the most abundant biopolymers found on Earth. Cellulose is the main structural component of the primary cell wall of green plants. It has attractive properties such as biocompatibility, biodegradability, and thermal and chemical stability. Chitin in terms of chemical structure and physicochemical properties is comparable to the cellulose. Similarly as cellulose, it is a hardly soluble substance indicating low chemical reactivity. The main natural sources of chitin are exoskeletons of arthropods and the cell walls of fungi. Cellulose and its derivatives are extensively used in industries such as wood and paper products, cosmetics, or pharmaceuticals. Areas of chitin and its derivatives application include biotechnology, cosmetics, agriculture, food products, textile and paper products, pharmaceuticals and medicals. Generally, instead of hardly soluble chitin, the chitin derivatives, e.g. chitosan, are widely used for industrial purposes. Recently, the comprehensive utilization of biopolymer resources has drawn much attention from the research communities. One of the most interesting application areas for cellulose- and chitin-based materials is the field of sustainable energy storage devices.

Generally, biopolymers could be used as components of energy storage devices, such as a separator, a polymer matrix of electrolyte, or an electrode binder. Paper sheets prepared from alkaline-resistant cellulose pulp have already been used to produce separators for commercially available alkaline batteries or supercapacitors. This was mainly due to their excellent wettability, low processing cost, high porosity, good mechanical properties and light weight. However, the literature survey reveals very limited investigation on the use of paper separators for lithium-based batteries. The apparent lack of interest may be related to the hygroscopic nature of cellulosic papers, its porosity and the absence of a thermal shutdown effect. Nevertheless, the low cost of cellulosic separators could make them of interest once solved the safety problems. Conversely, the cellulose derivatives, e.g. carboxymethyl cellulose, are already more often used as ecofriendly electrode binders, an alternative for commonly used fluorinated thermoplastic polymeric binders.

A different approach is the application of biopolymer as the polymer matrix of gel electrolyte for electrochemical capacitor. Cellulose and chitosan, a water-soluble chitin derivative, have already been successfully used as a host for a hydrogel polymer electrolyte. Hydrogels were prepared by soaking the regenerated biopolymer films in an aqueous electrolyte. Such a solution is one of the methods to reduce electrolyte leakage from the electrochemical storage device while remaining the electrochemical properties of liquid electrolyte. In practice, electrochemical capacitors based on hydrogel electrolytes have relatively low operating voltage limited to ca. 1 V. Since the energy density of electrochemical storage devices is strongly depended on the operating voltage, it is crucial to find the solutions exceeding an electrochemical stability of the biopolymer gel electrolytes. It seems obvious that the simplest way to solve that problem is to introduce a nonaqueous electrolyte into cellulose polymer matrix.

In this project, for the first time, will be presented the simple but novel idea of the preparing of gel polymer electrolytes by introducing electrochemically stable ionic liquid into a biopolymer matrix. The preparation procedure will be the modified version of the manufacture of cellulose hydrogels, which was previously presented in literature. The method parameters will be optimized during research project. The obtained materials will be used and widely characterized as components of the energy storage devices, which operate at relatively high voltage ranges. Additionally, for the first time non-derivative chitin processed in IL-based solvents will be used to fabricate hydrogel biopolymer electrolytes and biopolymer-based electrode materials. The obtained materials will be electrochemically characterized as components of supercapacitor cells.

The effect of undertaken studies will be the gaining of knowledge about the characteristics and the preparation method of novel biopolymer-based components for electrochemical storage devices. It is hoped the proposed solutions, as the efficient and ecofriendly alternative for current trends in the field of energy storage devices, could in the future interest the research community. The presented topic matches perfectly the sustainability trend of the searching for green solutions for science and industry.