Bipolar electrodes in electrochemical systems

The general aim of the project is to take advantage of electrochemical systems involving bipolar electrodes. In a typical arrangement of this kind a metallic conductor is placed in an electrolyte solution between two electrodes polarized by an external voltage and the conductor is not connected with the electrodes. Due to presence of electric field between the polarizing electrodes oxidation and reduction process can be triggered at opposite ends of the conductor and current flow between these ends occurs.

One of tasks proposed in our project will be development of electrochemical-optical analytical systems. In this case at one end of a bipolar electrode an electrochemical process of an analyte occurs, while on the second end, a complementary electrochemical process is observed, coupled with consumption / release of compounds which can be detected optically, using either UV/VIS spectrometry or fluorimetry.

These systems can be also used for purposes of new materials synthesis– due to release and consumption of various compounds at both ends of the electrode, new synthetic routes, mainly for inorganic compounds can be proposed. In this project we propose a method of synthesis of a salt / complex ZnX_2, using a compound KX. In this case cations K^+ are consumed at cathodic pole of the bipolar electrode (with potassium-selective membrane),while zinc ions are produced at the anodic end by dissolution of metallic zinc.

We are aiming also to apply various polarization modes using AC voltage or pulse mode of polarization, mainly for closed bipolar electrode systems. The pulse polarization mode can result in detection limit lowering due to reduction of capacitive current, while AC voltage application can be useful for implementation of electrochemical impedance spectroscopy procedures to study processes at bipolar electrodes. This method can be also applied to study charge transport phenomena e.g. in layers of conducting polymers used as bipolar electrodes or dispersions of conducting polymer nanoparticles, where wiring to electrochemical instrumentation is difficult or impossible.

We propose also studies on influence of external voltage / electric field on phenomena which are not typical redox processes. In this case we would like to concentrate on a method of conducting polymers nanoparticles synthesis in the presence of polyacrylate microspheres hosting a monomer. In this case the monomer is spontaneously released from the microsphere to a solution containing an oxidizing agent. In this case, polymerization process is induced close to the interface of the microsphere and solution, with formation of nanoparticles. Our aim is to study the influence of electric field on nanoparticles properties and ultimately to optimize the method of nanoparticles synthesis.

A very promising, however, underestimated issue concerning bipolar electrode arrangement is development and applications of "self-powered" mode. In this case polarizing electrodes are absent and the oxidation / reduction processes at the end of the conductor can occur spontaneously due to appropriate sequence of the redox potentials. A significant advantage of this arrangement is no need of polarizing apparatus. These systems can be used as electrochemical-optical analytical systems, with reaction of the analyte at one end of the conductor and complementary reaction at the second end, coupled with change of UV-Vis absorption or fluorimetric signal. In our project these systems will be also tested from the point of view of development of simple amperometric detectors working in the absence of external polarization.

We obtained also preliminary and promising results concerning a novel idea of double circuit self-powered systems and these studies will be continued and extended. In this arrangement two bipolar electrodes are present. At one of these electrodes a spontaneous process occurs with oxidation and reduction at opposite ends. This bipolar electrode is a voltage source triggering redox processes at the second bipolar electrode which can be used as electrochemical – optical analytical system. In this case one has a "driving" and "sensing" bipolar electrodes and the complete system will work spontaneously without external voltage stimulus.

The results can be useful to propose new electrochemical / optical analytical methods as well as new methods of materials synthesis and investigation. The scientific results will be published in leading international journals devoted to electrochemistry, chemistry of materials and analytical chemistry.