Research project objectives

Electrocatalytic reduction of organic halides is currently a popular topic of scientific research, because it is a very promising approach in organic electrosynthesis and water pollution remediation. Organic halides electroreduction on non-catalytic materials, such as glassy carbon, occurs at a very negative potentials. Implementing catalytic materials (e.g. Ag, Au, Hg) leads to a significant shift of reduction threshold to less negative values. Recently, bimetallic nanoparticles were introduced as novel electrocatalytic electrode materials with even stronger electrocatalytic activity toward reduction of organic halides. Use of such electrode materials is more economical than conventional bulk catalytic materials, due to higher surface to volume ratio and lower energy consumption of the process. The main disadvantages of nanoparticle electrodes are their insufficient stability and suspected toxicity. Additionally nanoparticles, in order to be used in electrocatalysis, have to be immobilized on supporting material. To this point, ordered bimetallic nanowire array electrodes have never been reported as electrode material for electrocatalytic reduction, despite their higher stability and anticipated similar efficiency, compared with nanoparticles. In the case of ordered nanowire array there is no need for additional supporting material.

The aim of this project is synthesis of ordered arrays of AgPd nanowires in porous anodic alumina templates and investigation of electrocatalytic properties of electrodes based on ordered AgPd nanowire arrays toward reduction of aliphatic halides (chloroform and/or bromoform) in water. Bimetallic nanowires should exhibit at least similar or even better electrocatalytic properties comparing to nanostructured monometallic silver or palladium electrodes.

Research project methodology

Project is divided into three parts. Firstly, ordered arrays of AgPd nanowires will be synthesized by two routes: (i) electrochemical codepositon of Ag and Pd; (ii) sequential electrochemical deposition of Ag and Pd cementation. Porous anodic alumina membranes, prepared by anodization and voltage detachment methods, will be used as templates for the synthesis of bimetallic nanowires. Secondly the morphology, composition, structure and surface area of synthesized electrodes will be determined by SEM, EDS, XRD, XPS and Pb underpotential deposition methods, respectively. Finally electrocatalytic properties of ordered arrays of AgPd nanowires electrodes will be examined. Because electrocatalytic reduction was rarely studied in protic solvents, therefore water was selected as reaction medium. Influence of the nanowire electrode composition and morphology on the electrocatalytic activity will be studied. All electrochemical measurements will be performed with Gamry potentiostat/galvanostat.

Expected impact of the research project on the development of science, civilization and society

To the date the ordered AgPd nanowire arrays have never been used as electrodes for the electrochemical reduction of organic halides. Such electrodes should exhibit at least similar or even better electrocatalytic activity compared to monometallic nanoparticle electrodes or bimetallic and monometallic bulk electrodes. It is expected, that reduction threshold of selected molecules (e.g., chloroform and/or bromoform) will be shifted effectively toward less negative potentials on synthesized nanostructural bimetallic electrodes. In this project chloroform and/or bromoform were selected as model molecules. They are sufficiently soluble in water and are known as common water pollutants (especially chloroform). Water was selected as a solvent because a mechanism of electroreduction in water is still not well understood, and metallic Ag electrodes exhibit improved catalytic activity in protic solvents. In the future, a direct determination of chloroform and/or bromoform and other organic halides concentration in wastewater could be possible on the electrodes based on materials developed in this project. Additionally, the ordered nanowire arrays should be more useful as electrodes, compared to nanoparticles, because they do not required additional supports, and should be more stable and similarly effective in electrocatalytic reduction of aliphatic halides. The ordered AgPd nanowire arrays electrodes could be introduced as actual alternative electrode for currently used bulk electrodes in both pollution remediation and organic electrosynthesis.