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Palladium based catalysts as components of composites for preparation of direct formic acid fuel cell electrodes

Fuel cells are devices that can generate electric energy whenever and wherever it is needed. Probably, in the future, fuel cells will replace batteries in portable equipment like mobile phones or laptops. Direct formic acid fuel cells (DFAFC) are expected to be among the first commercial applications of fuel cells as a power supply for portable electronics devices. DFAFC have many advantages such as higher power density, higher energy efficiency and higher electromotive force than methanol fuel cells. Also formic acid as a liquid is easy to handle and less toxic than methanol.

The main objective of PhD thesis was to develop and produce new efficient catalytic nanomaterials intended for the anode and cathode of low temperature direct formic acid fuel cell. The solutions proposed in the PhD thesis were aimed at decreasing costs of consumption of these materials and decreasing costs of formic acid used in DFAFC.

In the PhD study, palladium based catalysts were synthesized and characterized. The catalysts were prepared by reduction of palladium salt in the presence of the carbon supports. Ethylene glycol, formaldehyde, formic acid, sodium borohydride and hydrazine were used as reducing agents. As the supports Vulcan carbon black, Carbo Medicinalis Ligni (CML) and multiwall carbon nanotubes (MWCNTs) were applied. Before palladium deposition, selected supports were functionalized by treatment in concentrated nitric acid. Prepared catalysts were characterized by X-ray diffraction (XRD), thermogravimetric analysis (TGA), transmission electron microscopy (TEM), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), X-ray fluorescence spectroscopy (XRF) and cyclic voltammetry (CV). After the characterization, these catalysts were tested in direct formic acid fuel cell either in formic acid electrooxidation or oxygen electroreduction reactions.

In the thesis, gold and ruthenium were used as promoters of palladium catalysts in formic acid electrooxidation. The palladium-gold catalyst shows higher catalytic activity in formic acid electrooxidation than palladium catalyst prepared in the same method. In turn, palladium-ruthenium catalysts show higher stability in formic acid electrooxidation than the commercial palladium ones. The palladium-ruthenium catalysts allow to use cheaper formic acid of a lower purity grade. The reasons of activity decrease of palladium catalysts in formic acid electrooxidation have been also investigated. In addition, palladium catalyst have been designed and tested, as a cheaper replacement of platinum catalyst, in oxygen electroreduction reaction in DFAFC.