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Report on the PhD Thesis manuscript submitted by M. Peter Kúš,
"Thin Film catalysts for proton exchange membrane water electrolyzers and unitized regenerative fuel cells", Charles University

In order to overcome the increase of the energy demand, novel and efficient energy conversion systems are required for powering mobile and stationary devices. Hydrogen appears as the clean energy source because its unique product of oxidation is water which can be split to hydrogen and oxygen. These two processes occur in two devices which are fuel cell and water electrolyzer. For low operation temperatures, the corresponding systems named polymer electrolyte membrane fuel cell (PEM-FC) and water electrolyzer (PEM-WE) need a large scale commercialization. However, the cost of the electrodes materials made of noble metals is still high. A way of simplifying the two systems is to combine them in a unique device which is the unitized regenerative fuel cell. This new system operates in both fuel cell and electrlyzer modes. Therefore, one of the challenges in a such system is to develop for example efficient bifunctional electrodes able to oxidize water or hydrogen (OER and HOR) with a very low overpotential. In addition, the decrease the noble metals contents or their subtitution by other transition metals appears as a key point for reducing the cost of electrodes materials. It requires the development of novel strategy for fabricating electrodes materials. The PhD thesis submitted by M. Peter Kúš entitled "*Thin Film catalysts for proton exchange membrane water electrolyzers and unitized regenerative fuel cells*", deals with this hot topic by developing new electrodes materials for a PEM-WE and a URFC.

The PhD Thesis manuscript of M. Peter Kúš contents four main parts including the introduction and the conclusion.

In the introduction, M. Peter Kúš gave an overview on the hydrogen economy and its role for the sustainable future. In the same chapter, principles, basics of the three systems were explained as well as the challenge to overcome.

The second important part (experimental section) describes the techniques of fabricating the electrode materials, to characterize them and to perform electrochemical measurements. Indeed, M. Peter Kúš used the magnetron sputtering deposition method for fabricating the catalyst layer. The microscopy observations by SEM and AFM were also described as well as the characterizations by photoelectron spectroscopy. Various cell designs were tested in this work.

The main part of the PhD thesis is dedicated to the results and their analysis. The first merit of M. Peter Kúš is to design and build a PEM-WE and a PEM-URFC based on the expertise existed in the group. Due to the production of oxygen at the anode of PEM-WE, he pointed out the need of using Ti based plate at the oxygen electrode instead of carbon material which is usually serves as plate for PEM-FC. The TiN coated Ti plate have shown strong resistance to corrosion. M. Peter Kúš has reported that among several combinations, the Ir sputtered on TiC based sublayer has a good performance. The TiC sublayer loading was also evaluated in order to reach the optimized anode layer. Indeed, the current density at 1.9 V was about 2 A cm^{-2}. M. Peter Kúš has also optimized the amount of the ionomer (Nafion®) in the catalytic layer. Indeed, 15% of Nafion® seem to be the best composition. From his systematic investigations on PEMWE, M. Peter Kúš demonstrated that the material made of TiC nanoparticles and Nafion® ionomer can be a good support. The dispersion of the catalysts on the top of the catalysts support already hot-pressed is novel. The sputtered layer of Ir showed a corrosion resistance after ageing test. The XPS analysis permitted to confirm the presence of Ir oxides. Based on his systematic investigations, M. Peter Kúš was able to establish experimental conditions for a PEM-URFC operation. Indeed, a anode material composed of Ir and Pt was sputtered as a thin film of Pt-Ir on TiC based sublayer. This bifunctional anode (for HOR/OER) was characterized by SEM and AFM and XPS. The round-trip efficiencies at 1 A cm^{-2} of all combinations are higher than 41%.

Overall, M. Peter Kúš has performed an original and very interesting research for his PhD project which offers low catalysts loading for building efficient PEM-WE and PEM-URFC. M. Peter Kúš draws conclusions that are supported by experimental results. Based on my evaluation, the manuscript of M. Peter Kúš meets all the requirements for a PhD thesis of the Charles University.

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