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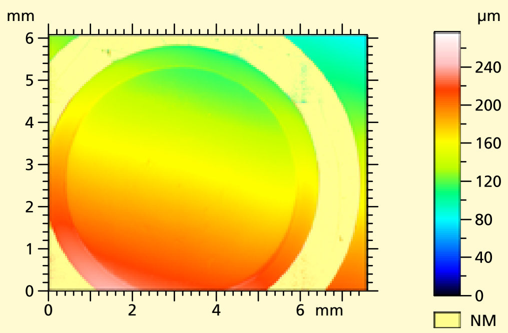

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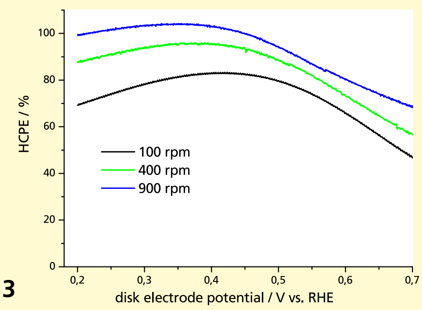

3

1 *Rotating ring-disc electrode.*

2 *Microscopic profile of a catalyst-coated RRDE.*

3 *Current efficiencies of hydrogen peroxide at an optimized catalyst.*

ELECTROCATALYSTS AND ELECTRODES FOR ELECTROCHEMICAL SYNTHESIS

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Introduction

Electrosynthesis enables a more precise control of the energy input (via the current or electrode potential) than is possible using thermal methods. As certain reactions such as the breaking of C-C bonds are strongly inhibited in electrochemical processes, electrochemistry can be used to achieve a higher selectivity in a variety of reactions such as partial oxidations or reductions. Widespread industrial application has not been possible so far due to the high operating costs. Perspective decreases in the price of electricity, however, have led to increased interest in electrochemical processes. Fraunhofer ICT works to support this development with its expertise in the field of electrocatalysis, electroanalytics and electrochemical reactors, in particular with regard to continuous electrochemical processes.

Synthesis of catalysts

Fraunhofer ICT can synthesize and characterize the following material classes for electrocatalysis on a laboratory scale:

- Nanoparticles of noble metals and their alloys
- Core-shell nanoparticles in a continuous process
- Metal and mixed oxides
- Surface-modified carbon as a support
- Corrosion stable supports based on metal oxides or carbides

Characterization

The main research focus at Fraunhofer ICT is electrochemical characterization, in particular to determine product composition and the influence of secondary reactions.

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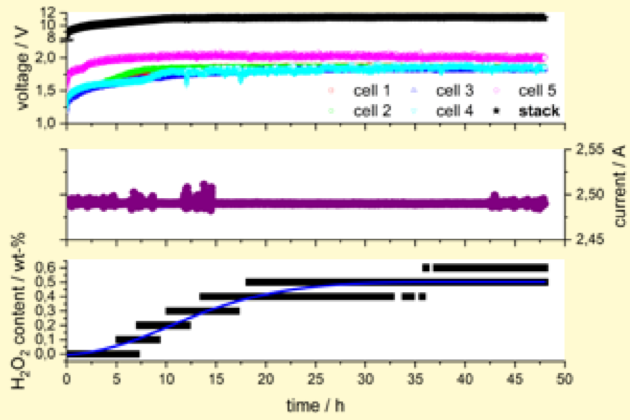

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Methods include:

- Rotating (ring-)disc electrode measurements
- Differential electrochemical mass spectrometry
- Electrode reactions under differential reaction conditions with optical product measurement

Electrode design

Fraunhofer ICT has experience in the production of gas diffusion electrodes (GDEs), porous transport electrodes (PTEs) and catalyst-coated membranes (CCMs). These electrodes are produced, for example, through the hot spraying of catalyst inks with an optimized formulation. As an alternative, coating can be carried out by sputtering. The structure of the catalyst layer is adapted to the requirements of the reaction, based on the results of the catalyst test.

Important design parameters include:

- Loading with the catalyst
- Porosity
- Geometry of the electrode
- Lateral distribution of the catalyst(s)

Where loading is high, high turnovers can be achieved within specific parameters. However, high loads also increase the probability of secondary reactions. The occurrence of secondary reactions can also be influenced by the geometry of the electrode. Elongation in the direction of flow favors secondary reactions, while shorter geometries prevent them. The occurrence of undesired secondary reactions can also be influenced by the cell geometry e.g. the width of the gap or size and structure of flow channels.

In discussion with our customers we can develop electrode designs for specific applications.

Examples

Generation of hydrogen peroxide through partial reduction of oxygen

The partial reduction of atmospheric oxygen to hydrogen peroxide is a process suitable for the local generation of hydrogen peroxide. The only potential by-product of the complete reaction is water. To ensure a high yield of hydrogen peroxide, it is necessary to prevent a large-scale reduction to water, either in the initial stage or as a secondary reaction. For this purpose, extensive RRDE investigations were carried out. It has been demonstrated that PdxAuY alloys have a high selectivity for the formation of hydrogen peroxide, and a low reduction activity. The catalyst is produced as a supported catalyst on Vulcan XC72R©.

However, tests at actual gas diffusion electrodes have shown that the yield of hydrogen peroxide produced with an ultra-thin sputtered platinum layer is higher than the yield achieved with a supported PdAu/C catalyst. This was attributed to a shorter residence time. Optimizing the cell design toward high flow rates nabled the production of hydrogen peroxide solutions with accumulated 0.5 % wt% content in 100 cm² cells.

Partial oxidation of alcohols to aldehydes

Aldehydes can be simply obtained via the oxidation of primary alcohols. An electrochemical process avoids risks to the direct partial oxidation which result from mixing alcohols with oxygen. The probability of breaking the C-C bond is also low. An overreaction to acid must be avoided. Fraunhofer ICT has demonstrated that low loading with tin-doped platinum in combination with short residence times and a low pH achieves this aim.

Our offer

- Analysis of synthesis options in view of applying electrochemical (partial) reactions
- Selection of a suitable cell technology
- Development, testing and screening of electrocatalysts
- Transfer to electrodes on a larger laboratory scale (up to 200 cm²)
- Testing in single cells and short stacks
- Optimization of the operational management in consideration of downstream processes

4 *Single cell, 10 cm², for gas diffusion electrode test.*

5 *5-cell stack with 100 cm² electrodes.*

6 *Time dependence of Voltages and current in operation and accumulated hydrogen peroxide content in the circuit.*