Influence of the catalyst loading on the DMFC efficiency

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Funded by: AiF
Period: 01.12.2009 – 31.05.2012

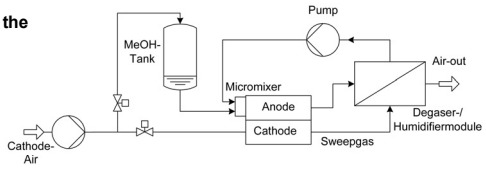
Motivation

The market for portable consumer-electronics like gps, mobile phones or mp3-players is rising rapidly and therefore also the demand for efficient, low-cost power sources which must yield adequate power-output while maintaining small volume to weight ratio. Especially in remote or isolated areas where no connection to the electricity network is possible, their working time is still restricted to the inherent capacity of the integrated battery or accumulator. Since the energy density of methanol is up to 50 times higher than that of a conventional battery, its use as energy carrier in a direct methanol fuel cell (DMFC) for power supply applications is very attractive.

Objectives

A portable, orientation-independent 5W battery charger with methanol as main energy source will be developed in this project in collaboration with the *Zentrum für Brennstoffzellen Technik* (ZBT) in Duisburg and the *Institut für Mikroverfahrenstechnik* (IMVT) in KIT Karlsruhe.

Fig. 1: Concept of the battery charger



The charger comprises a methanol tank, a µ-DMFC, a Li-ion battery as buffer, a methanol/water-mixer, a CO_2 filtration system and a module for water recovery (see fig. 1). The µ-DMFC stack will be made of 10-12 single-cells and should work at 40-60°C. The main objective of the KWI aims at the development of an efficient membrane-electrodes-assembly (MEA). The first works focus on the optimization of the catalyst loading and the construction of an apparatus for the test of the DMFC in different positions.

Background

In a DMFC, methanol is catalytically oxidized at the anode to carbon dioxide, electrons and protons.

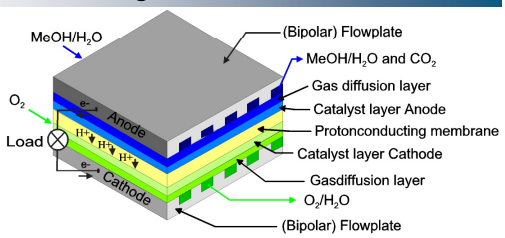


Fig. 2: Simplified sketch of a single-cell

Anode: $CH_3OH + H_2O \rightarrow 6\ H^+ + 6\ e^- + CO_2$
Cathode: $3/2\ O_2 + 6\ H^+ + 6\ e^- \rightarrow 3\ H_2O$

Overall: $CH_3OH + 3/2\ O_2 \rightarrow 2\ H_2O + CO_2$

Under the influence of the electric field the protons are transported from the anode to the cathode via the polymer membrane electrolyte and react with oxygen to water. The MEA is made by pressing the electrodes together with the membrane (see fig. 2). In order to obtain higher voltages, single-cells are connected in series to built-up a fuel cell stack.

Experimental: catalyst layer and MEA preparation

• $Pt_{50}Ru_{50}$- and Pt catalysts were prepared by impregnation on VulcanXC72R according to a method developed by Auer et. al. [1] as outlined in fig. 3. For details see Ref. [2].

• The catalyst ink was sprayed onto a carbon paper as gas diffusion layer (GDL) and sintered at 80°C.

• MEAs were fabricated by hot-pressing the Nafion117 membrane with the anode and cathode at 6 bar and 130°C for 4 min.

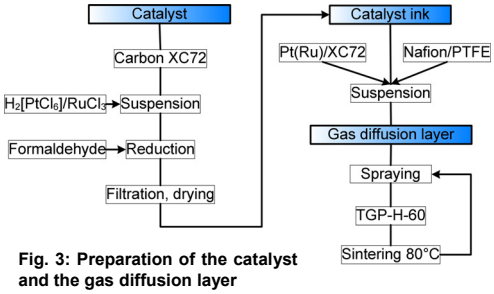


Fig. 3: Preparation of the catalyst and the gas diffusion layer

• The tests of MEAs with different Pt loading at the anode and cathode were carried out in a 5 cm^2 commercial DMFC .

Evaluation of MEA performance for different Pt loadings, c, T

• The influence of the catalyst loading, methanol concentration and working temperature on DMFC performance was studied (see results in fig. 4).
• Impedance and methanol permeation measurements were routinely performed to characterize the MEA (results not shown here).

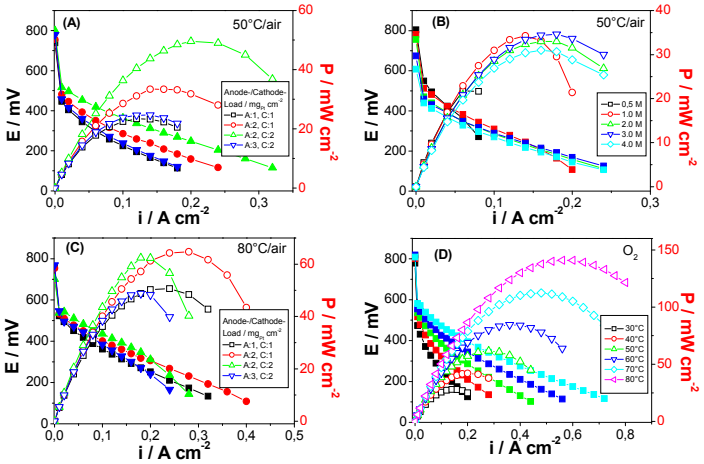


Fig. 4: E/i- and P/i curves (open symbols) for (A) different catalyst-loadings (2M MeOH) and (B) different MeOH-concentrations (2 mg_{Pt} cm^{-2} at anode/cathode) both at 50°C/air, (C) different loadings at 80°C/air and (D) different temperatures (2 mg_{Pt} cm^{-2} at anode, cathode) with O_2 and 2M MeOH. Flow: MeOH=10 ml min^{-1}, O_2=500 ml min^{-1}, air=700 ml min^{-1}. p=1.2 bar.

• A maximum power density of 32 and 25 mW cm^{-2} was calculated at 50°C in air for a catalyst loading of 2 mg_{Pt} cm^{-2} at the anode and cathode with 1 M and 2 M MeOH, respectively.
• The same MEA was measured at 80°C with O_2 as cathode feed: a max. power-density of 141 mW cm^{-2} with 2 M MeOH at 1.2 bar was recorded.

Assembly of a new apparatus for fuel cell tests

In order to test the orientation dependence of the µ-DMFC on its performance a new fuel cell setup has been constructed that includes:

• 180° horizontally and vertically pivotable fuel cell fixation (fig. 5).

• Computer-controlled recording of the E/i-curves and impedance measurements.

• MeOH sensors at the inlet and outlet of the fuel cell anode.

• CO_2 sensors at the anode and cathode outlets.

• mass flow and pressure controllers….

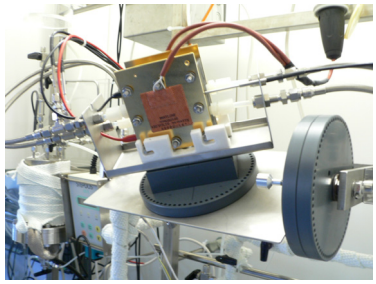


Fig. 5: Image of the pivotable fixation with a 5 cm^2 single-cell.

Summary and outlook

• The best results in air at 50°C have been obtained with a catalyst loading of 2 mg_{Pt} cm^{-2} both at the anode and cathode in 1 M methanol with catalysts prepared by the impregnation method.
• Working parameter and electrode design have to be optimized, depending on the results obtained at different positions.
• Further works will focus on the design and optimization of the µ-DMFC stack and other compounds in cooperation with the partners.

Acknowledgements

We thank to AiF for financial support, our project partners and KWI workshop for their cooperation and help.

Literature

[1] E. Auer, A. Freund, T. Lehmann, K. A. Starz, R. Schwarz and U. Stenke, U.S. Pat. 6,007,934 1999.
[2] J.F. Drillet, H. Bueb, R. Dittmeyer, U. Dettlaff-Weglikowsk and S. Roth, *Journal of The Electrochemical Society, 156 F137 (2009)*