MEA fabrication and characterization for portable DMFC applications

N. Bogolowski, J.-F. Drillet
e-mail: bogolowski@dechema.de

Funded by: BMWi via AiF
Period: 01.12.2009 - 31.05.2012

ALLIANZ INDUSTRIE FORSCHUNG
Gefördert durch:
Bundesministerium für Wirtschaft und Technologie

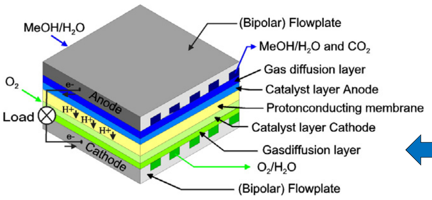
Motivation

Actual situation:
Market for **Portable consumer-electronics** like gps, mobile phones or mp3-players is rising rapidly. They usually have an integrated **battery**, which must yield adequate power-output and have small volume to weight ratio.

Drawback:
The **working time is** still restricted to the inherent capacity of the integrated battery or accumulator when no connection to an electrical network is available
(i.e. outdoor-activities).

Our strategy:
Direct methanol fuel cell (DMFC) for power supply:
- ✓ Energy density of methanol is up to 50 times higher than that of a conventional battery
- ✓ Methanol can easily be transported in catridges (liquid)
- ✓ very fast refuelling time

Fig. 1: DMFC single-cell and electrode reactions



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

Objectives

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

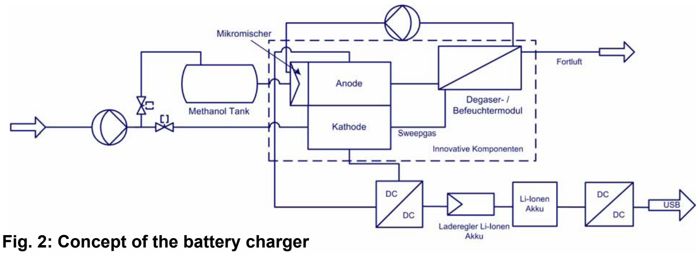


Fig. 2: Concept of the battery charger

The main objective of the KWI aims at the development of an efficient membrane-electrodes-assembly (MEA). The work focusses on the optimization of the catalyst loading, characterization of the prepared MEAs, the construction of an apparatus for the test of the DMFC in different orientations and the characterization of the Li-Ion battery.

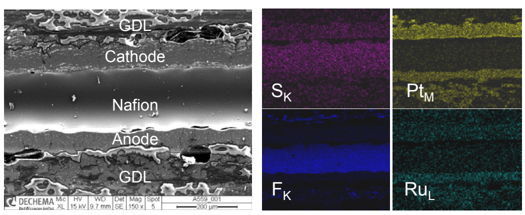
Catalyst synthesis and MEA characterization

- $Pt_{50}Ru_{50}$- and Pt-catalysts were prepared by impregnation on Vulcan XC72. Catalyst inks (cat/C + 10wt% Nafion + 20wt% PTFE) were sprayed either onto Toray carbon paper (TGP-H-60) or Freudenberg (CH2315CX190) with microporous layer as gas diffusion layer (GDL). MEAs were fabricated by hot-pressing the electrodes with a Nafion 117 or 115 membrane at 130°C, 7bar, 4min.
- MEA characterization with U/i-curves, EIS, methanol permeation and CO_2 measurements in a 5 cm^2 pivotable laboratory cell.
- Influence of methanol concentration, backing pressure, cell temperature and orientation on cell performance was investigated.

MEA characterisation with SEM

SEM image and EDX mapping of a MEA after characterisation in the DMFC is shown in fig. 3:
- Ru was detected on both the anode and cathode-side (Ru-crossover).

Fig. 3:SEM image of a MEA with 2mg$_{Pt}$cm^{-2} both on anode and cathode side after charact. in DMFC (left) and EDX images of the Element distribution of S,F,Ru,Pt (right)



MEA characterization in DMFC

In a first approach, the influence of anode & cathode catalyst loading on MEA performance was evaluated. The results are presented as follows:

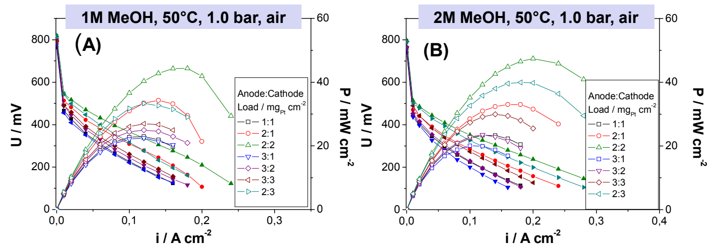


Fig. 4: U/i- and calc. P/i-curves (open symbols) recorded from different catalyst-amount with (A) 1M MeOH and (B) 2M MeOH, both at 50°C/air, ambient pressure.

- The highest power-density of approx. 42 mWcm^{-2} was obtained with 2mg$_{Pt}$cm^{-2} loading both on the anode and cathode in 1-2M MeOH
- Decreasing power-density with higher Pt-load (transport limitation?) observed.

In order to improve the MEA-performance, the catalyst/support weight ratio was increased up to 60wt% at the cathode. Alternatively, a GDL with microporous-layer (MPL, **Freudenberg CX190**) and also **Nafion 115** as (thinner) membrane-material were tested:

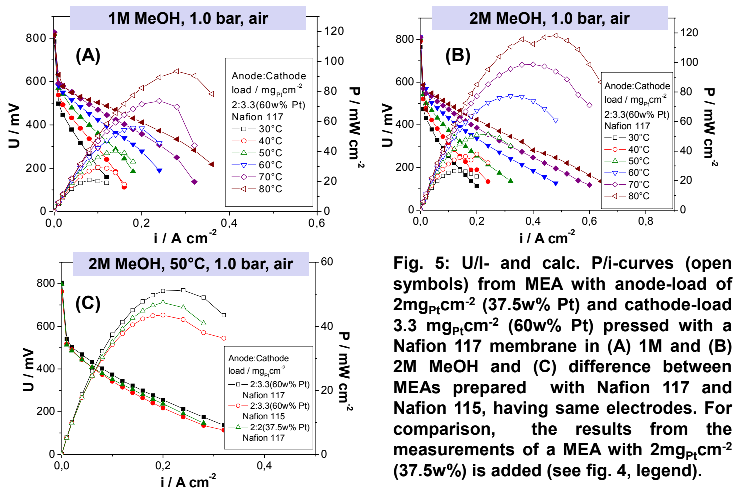
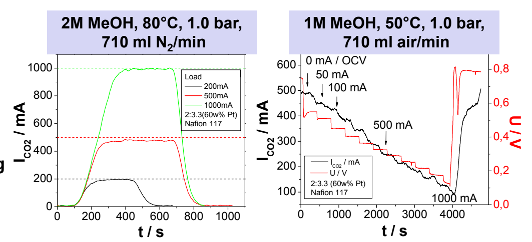


Fig. 5: U/I- and calc. P/i-curves (open symbols) from MEA with anode-load of 2mg$_{Pt}$cm^{-2} (37.5w% Pt) and cathode-load 3.3 mg$_{Pt}$cm^{-2} (60w% Pt) pressed with a Nafion 117 membrane in (A) 1M and (B) 2M MeOH and (C) difference between MEAs prepared with Nafion 117 and Nafion 115, having same electrodes. For comparison, the results from measurements of a MEA with 2mg$_{Pt}$cm^{-2} (37.5w%) is added (see fig. 4, legend).

- Enhancement of the MEA performance with higher wt% Pt in the cathode in combination with a MPL/GDL cathode in air at 1bar:
  - P_{400mV} = 32 and 45 mWcm^{-2} at 50 and 60°C,
  - P_{max}=110 and 50 mWcm^{-2} at 80 and 50°C, respectively.
- Higher performance of MEA with Nafion 117 compared to that with Nafion 115.

The CO_2 concentration was measured at the cathode (e.g. see fig. 6). Corresponding faraday current value decreases with increasing current load: less MeOH-crossover.

Fig. 6: Calculated Faraday currents from CO_2 signal at (A) anode while performing MeOH permeation exp. at const. load for calibration and (B) cathode while recording U/i-curves (current steps, air).



Summary and outlook

- The new fuel-cell setup has been tested succesfully, also a battery testbox has been integrated. Possibilty to monitor CO_2-formation at the cathode (anode) side.
- The best results $P_{400mV / 60°C / air}$ = 45 mWcm^{-2} have been obtained with a catalyst loading of 2 mg$_{Pt}$cm^{-2}$_{(37w\%\ Pt)}$ and 3.3 mg$_{Pt}$cm^{-2}$_{(60w\%\ Pt)}$ on MPL/GDL at the anode and cathode respectivly in 2 M methanol.
- Further works will focus on the design and optimization of the µ-DMFC stack and other compounds in cooperation with the partners.

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