MEA fabrication and characterization for portable DMFC applications

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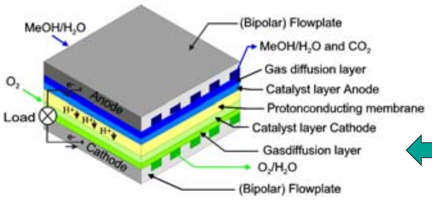
Motivation

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 has been developed in collaboration with the *Zentrum für Brennstoffzellen Technik* (ZBT) in Duisburg and the *Institut für Mikroverfahrenstechnik* (IMVT) at the KIT in Karlsruhe.

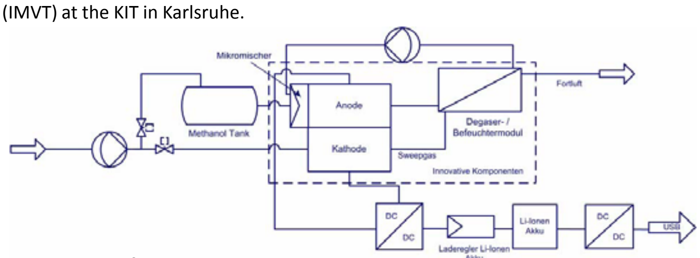


Fig. 2: Concept of the battery charger

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

Catalyst synthesis and MEA characterization

- $Pt_{50}Ru_{50}$- and Pt-catalysts were prepared by impregnation of H_2PtCl_6 and $RuCl_3$ in H_2O/CH_2O and CH_2O, respectively at 80°C 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).

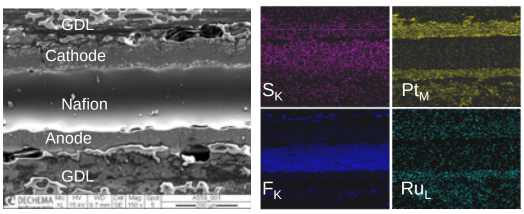


Fig. 3:SEM image of a MEA with 2mg$_{Pt}$cm^{-2} both on anode and cathode side after tests in DMFC (left) and EDX images of the element distribution of S, F, Ru, Pt (right)

MEA characterization in DMFC

1. Influence of catalyst loading and MPL

First, the influence of anode & cathode catalyst loading both with **Toray TGPH60** GDL on MEA performance was evaluated. The most efficient loading was 2 mg$_{Pt}$cm^{-2} at anode and cathode 2:2 (fig. 4A). Then, the influence of the microporous layer at the cathode (MPL, **Freudenberg CX190**) on cell voltage was investigated at different temperatures for the 2:2 catalyst loading (fig. 4B).

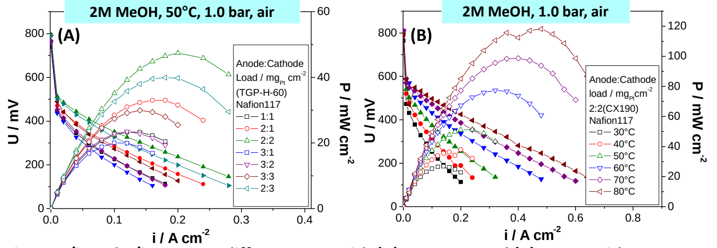


Fig. 4: U/i- and P/i-curves at different MEA with (A) TGP-H-60 and (B) CX190 with MPL.

- Best performances with 2:2 Pt loading for MEA without MPL cathode: P_{max}= 50 mWcm^{-2} at 50°C
- By using MPL/GDL cathode enhancement of the MEA performance was observed for T>60°C: P_{max}= 77 and 114 mWcm^{-2} at 60 and 80°C, respectively.

2. Influence of membrane thickness, commercial PtRu, T and cMeOH

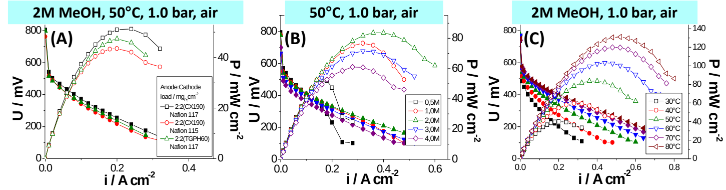


Fig. 5: U/I- and P/i-curves of MEAs with 2 mg$_{Pt}$cm^{-2} (37.5wt% Pt) both at the anode and cathode & MPL cathode; (A) Nafion 117 or Nafion115, (B) & (C) PtRu HiSpec12100 (50wt% Pt)

- No increase of cell power density by using Nafion115 at 50-80°C (fig. 5A).
- About 10% and 15% higher P_{max} and P_{400mV} by using commercial 50wt% PtRu catalyst in combination with as-prepared Pt catalyst on MPL cathode, respectively.
- Best results obtained with 2 M MeOH at 50-80°C cell temperature (fig. 5B/C)

Table 1: Measured power densities P_{max} and P_{400mV} at different T with 2M MeOH/air/1bar

T / °C	TGPH60/TGPH60		TGPH60/CX190		HiSpec-TGPH60/CX190	
	P_{max} / mWcm^{-2}	P_{400mV} / mWcm^{-2}	P_{max} / mWcm^{-2}	P_{400mV} / mWcm^{-2}	P_{max} / mWcm^{-2}	P_{400mV} / mWcm^{-2}
50	47	28	51	32	83	41
60	53	33	77	45	103	54
70	57	40	99	72	120	72
80	50	40	114	85	131	80

3. CO_2 measurements at the cathode with NDIR sensor (Vaisala)

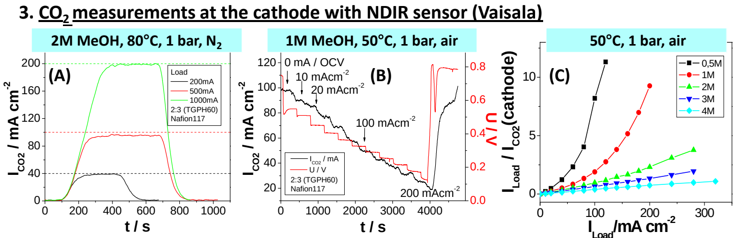


Fig. 6: Calculated Faraday currents from CO_2 signal at (A) Pt anode while performing MeOH permeation exp. at const. load for calibration, (B) cathode while recording U/i-curves (current steps 300s) and (C) ratio between calc. CO_2 signal and load.

- Good correlation between measured CO_2 production (I_{CO2}) and applied current (I_{Load}).
- Decrease of CO_2 production with increasing current load: less MeOH-crossover
- High I_{Load}/I_{CO2} ratio means high MeOH utilization; It should be as high as possible.

Summary and outlook

- The best results $P_{400mV/60\ C/air}$ = 54 mWcm^{-2} have been obtained with a catalyst loading of 2 mg$_{Pt}$cm^{-2}$_{(50w\%\ Pt,\ HiSpec\ 12100)}$ and 2 mg$_{Pt}$cm^{-2}$_{(37.5w\%\ Pt)}$ on MPL/GDL at the anode and cathode respectivly in 2 M methanol at ambient pressure.
- 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 BMWi for financial support, our project partners for excellent cooperation and DFI workshop for construction of the cell and test apparatus.