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).

Fig. 1: DMFC single-cell and electrode reactions

Anode: \( \text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow 6\text{H}^+ + 6\text{e}^- + \text{CO}_2 \)
Cathode: \( 3/2\text{O}_2 + 6\text{H}^+ + 6\text{e}^- \rightarrow 3\text{H}_2\text{O} \)
Overall: \( \text{CH}_3\text{OH} + 3/2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2 \)

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 cartridges (liquid)
- Very fast refuelling time

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/Ru oxides and Pt-catalysts were prepared by impregnation on Vulcan XC72. Catalyst inks (ca. 10%wt Nafion + 20vol% 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 Naflon 117 or 115 membrane at 130°C, 7bar, 4min.
- MEA characterization with I/i-curves, EIS, methanol permeation and CO2 measurements in a 5cm2-pivotal 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 2mgPt/cm² both on anode and cathode side after characterisation in DMFC (left) and EDX images of the Element distribution of S,I,F,Ru,Pt (right)

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 pressure.
- The highest power-density of approx. 42 mWcm⁻² was obtained with 2mgPt/cm² loading both on the anode and cathode with Toray GDL in 1-2M MeOH.
- Decrease in power-density with higher Pt-load (transport limitation) observed.

In order to improve the MEA-performance, a GDL with microporous-layer (MPL, Freudenberg CX190) for the cathode side and also Naflon 115 as (thinner) membrane-material were tested:

- Enhancement of the MEA performance by using MPL/GDL cathode in air at 1bar:
  - \( P_{\text{MEC}} = 32 \) and \( 45 \) mWcm⁻² at 50 and 60°C.
- Higher performance of MEA with Naflon 117 compared to that with Naflon 115, having similar electrodes. For comparison, the results from the measurements of a MEAs with 2mgPt/cm² (37.5%Pt) and no MPL (TGP(H-60)) is added (see fig. 4).

The CO₂ concentration was measured at the cathode (e.g. see fig. 6). Corresponding faraday current value decreases with increasing current load: less MeOH-crossover.

Fig. 5: Calculated Faraday currents from CO₂ signal at (A) anode while performing MeOH permeation exp. at constant load for calibration and (B) cathode while recording U/i-curves (current steps, air).

Fig. 6: Calculated Faraday currents from CO₂ signal at (A) anode while performing MeOH permeation exp. at constant load for calibration and (B) cathode while recording U/i-curves (current steps, air).

- Enhancement of the MEA performance by using MPL/GDL cathode in air at 1bar:
  - \( P_{\text{MEC}} = 32 \) and \( 45 \) mWcm⁻² at 50 and 60°C.
  - \( P_{\text{MEC}} = 110 \) and \( 50 \) mWcm⁻² at 80 and 80°C, respectively.
- Higher performance of MEA with Naflon 117 compared to that with Naflon 115.

Summary and outlook

- The new fuel-cell setup has been tested successfully, also a battery testbox has been integrated. Possibility to monitor CO₂-formation at the cathode (anode) side.
- The best results \( P_{\text{45min}/50^\circ\text{C}} \) \( = 45 \) mWcm⁻² have been obtained with a catalyst loading of 2mgPt/cm² (25%Pt) and 2mgPt/cm² (37.5%Pt) on MPL/GDL at the anode and cathode respectively in 2M methanol.
- Further works will focus on the design and optimization of the μ-DMFC stack and other compounds in cooperation with the partners.

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