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Direct DME high temperature PEM fuel cells

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Outline

Powering small and medium sized electronic devices can be achieved with direct HT-PEMFC. Hydrogen is the best fuel, but low volumetric energy density prevents it from successful use as energy source. Another commonly used fuel is methanol (MeOH), which has lower conversion efficiency, but the ease of handling and storage counterbalance this. The concerns about methanol are its toxicity and the substantial fuel crossover effect.

Dimethyl ether (DME) is a fuel similar to methanol, it is easily stored as a liquid at 6 bar or -25 °C. The vapour pressure is that between propane and n-butane, therefore DME can be handled using existing LPG infrastructure. Another benefit of DME is that it is not toxic [1].

The limited number of attempts reported in literature showed poor performance with DME at temperatures below 100 °C. The reasons for this are several – poor kinetics, large degree of fuel crossover and the low solubility of DME in water. All of those factors are greatly affected by temperature. The problem with solubility is completely avoided by raising the temperature above the boiling point of water, as the cell will no longer be fed with a liquid solution but with gas.

The objective of this study is to determine whether or not DME can be used for powering PEM fuel cells at elevated temperatures and compare the performance with DMFC and hydrogen fed fuel cell.

Results from 150 and 200 °C sequence

Fuel cell performance sequences with H_2 – DME – MeOH – DME – H_2 can be seen on Figure 3. As expected, hydrogen performs best for both temperatures. DME performance is poor at 150 °C and cannot compete with methanol, but with increasing temperature performance of DME FC comes in range of DMFC, which is encouraging. Another effect is that MeOH apparently has an effect on the latter behaviour of the fuel cell, as it performs better with both DME and H_2 after the run with methanol. This is in accordance with literature, where Mench et.al. [2] reported increase in fuel cell performance upon pre-treatment with methanol.

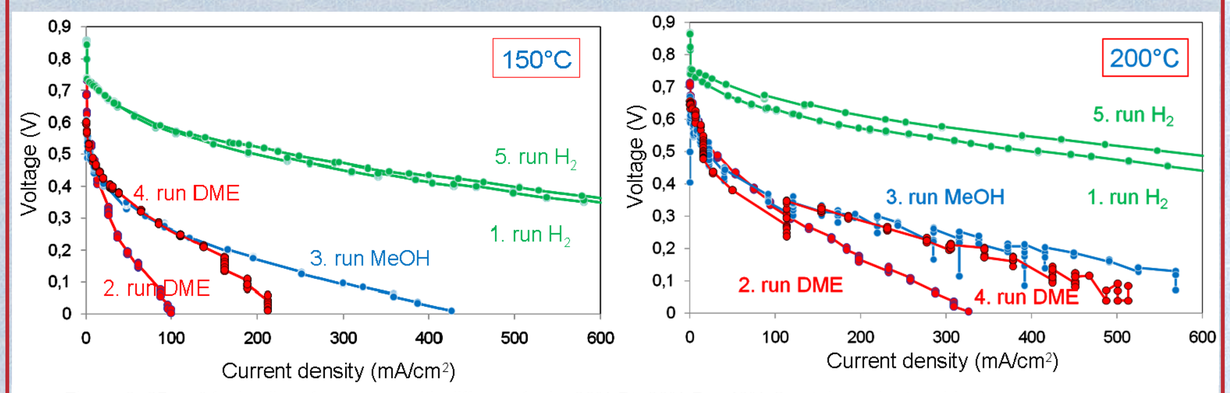

Figure 3: 25 cm² fuel cell performances with different fuels. 30% Pt, 30% Ru, 40% C catalyst, air at ambient pressure as oxidant.

Experimental

A testing station has been constructed for single cell tests. A photograph of the setup is given on Figure 1 and flow diagram on Figure 2. The fuel containers for DME and methanol were built in the system, while hydrogen and air were supplied from external source. The cell tests were performed at ambient pressure and different temperatures ranging from 150 – 225 °C where fuels were changed in a following sequence: H_2 – DME – MeOH – DME – H_2 for the same cell at given temperature. Air was used as oxidiser. Polarisation curves were recorded using a galvanostat connected with a PC. The cells tested utilised H_3PO_4-doped PBI membranes as electrolyte, standard DTU 0.7 mg/cm² Pt/C as cathode and anodes prepared from commercially available Pt-Ru/C catalyst powder with 1 : 1 Pt to Ru atomic ratio and 40 % carbon. PBI and H_3PO_4 were added to the powder and dispersed in formic acid. The slurry was then sprayed on wet-proof carbon cloth by hand and dried at 100 °C. The MEAs were hot-pressed at 150 °C and 100 kg/cm² for 7 minutes. The theoretical metal loading of the catalyst was 4 mg/cm².

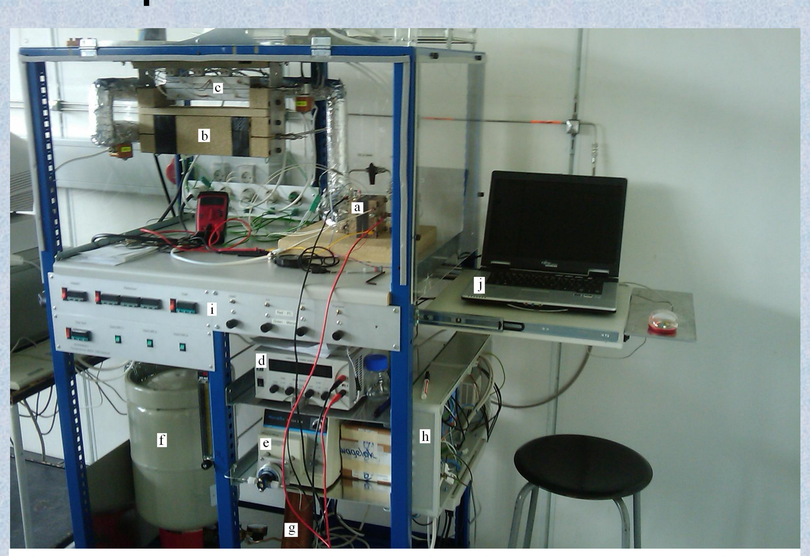

Figure 1: The complete experimental setup. a - fuel cell, b – heater, c – reformer, d – load, e – water pump, f – DME flask, g – copper coil, h – control box containing ICP-CON modules, i – control panels and j – PC.

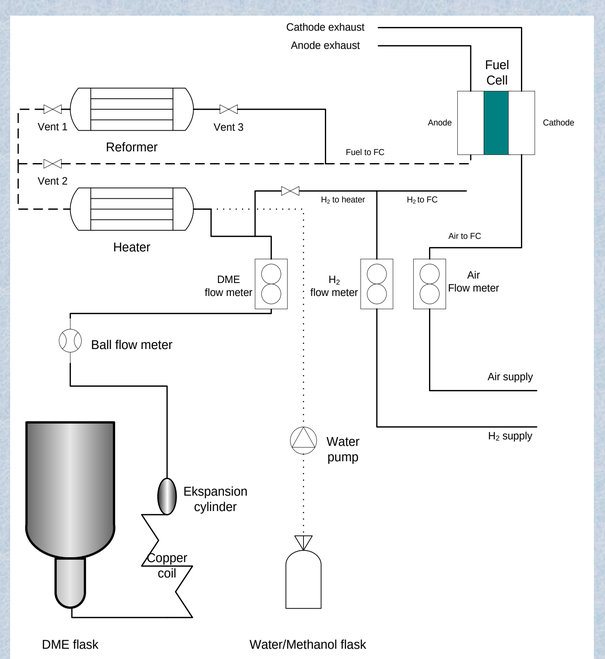

Figure 2: Flow diagram. Dotted line indicates liquid water tube. Dashed lines indicate the heated part of the tubing.

Temperature dependance

The cell was tested at 4 different temperatures from 150 to 225 °C. The polarisation curves are given on Figure 4. The performance increases with increasing temperature until 225 °C. At that temperature the cell began to show signs of degradation with increase in iR-loss. The phenomenon was expected, as it is known that PBI membranes are not stable above 200 °C [3].

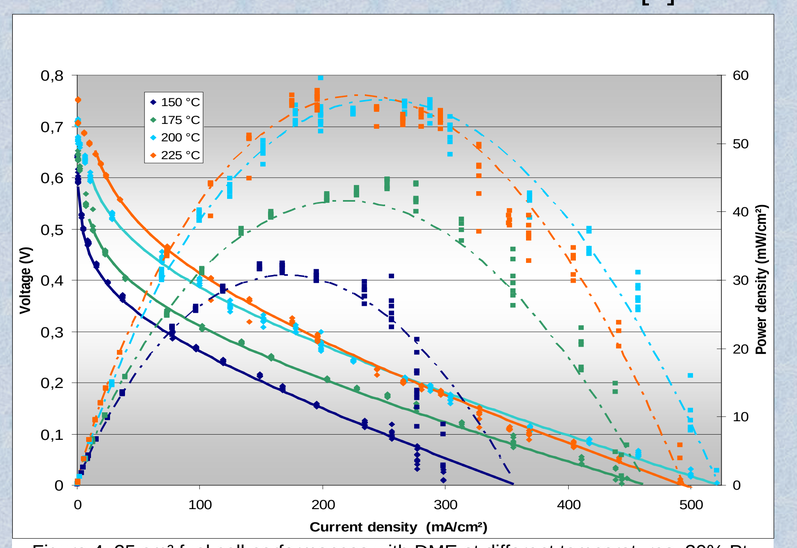

Figure 4: 25 cm² fuel cell performances with DME at different temperatures. 30% Pt, 30% Ru, 40% C catalyst, air at ambient pressure as oxidant.

The best performance of 40 mW/cm² for direct DME fuel cell at ambient pressure was reported by Yu et.al [4]. The best peak performance obtained in this study was 65 mW/cm² (see Figure 5), thus showing better results already in early stages.

DME vs. MeOH

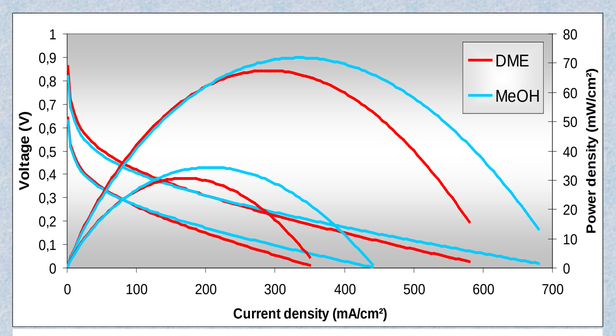

Figure 5: Comparison of 25 cm² fuel cell performance at 150 and 200 °C operated with DME and MeOH. 30% Pt, 30% Ru, 40% C catalyst, air at ambient pressure as oxidant.

From Figure 5 it is clear that methanol is still superior to DME, but the difference in peak performance at higher temperature is only 5 mW/cm². Optimising the composition of the catalyst towards DME operation is expected to give better performance of direct HT-PEMFC than DMFC in near future.

Conclusion

The conducted work showed that it is possible to use dimethyl ether directly in high temperature PEM fuel cell. Although the peak performances obtained in the study are slightly lower than that of direct methanol fuel cell DME is considered competitive in the position as hydrogen substitute for powering fuel cells small and medium sized electronic devices. The future work should focus on finding better materials and compositions for the anode catalyst, together with optimisation of operating conditions.

References

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