PERFORMANCE AND DURABILITY OF ELECTROSPRAYED PEMFC CATALYST LAYERS

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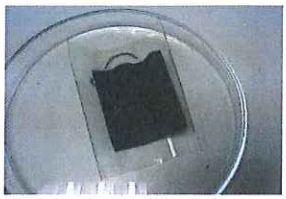
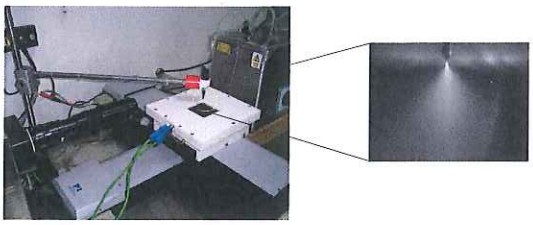
Catalyst coated membranes (CCMs) prepared by an electrospray technique have been evaluated for use in proton exchange membrane fuel cells (PEMFCs). Catalyst layers with Pt/C catalyst (20, 40, and 60 Pt wt%) were deposited on the cathode side of a polymeric membrane (Nafion NR212) with a commercial electrode on the anode (BASF, 0.25 mgPt/cm²). The electrosprayed catalyst layers show improved mass transport performance and lower electric resistance in comparison with standard commercial PEMFC electrodes. Durability testing via start-stop cycling at 80 ºC, 100% RH, atmospheric pressure and open circuit showed no deterioration in performance after 20 cycles. Localised measurements of electrode potential across the active area of the cell were applied to obtain information about the homogeneity of current distribution. Measurement of relative humidity in the flow-field channels will be used to investigate water transport in a future study.



Preparation of catalyst layers

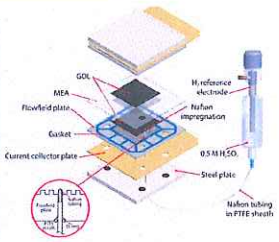


The electrospray technique is based on the deposition of a solid material in a suspension under the influence of an intense electric field. For catalyst layer deposition, a suspension is prepared with Pt/C catalyst powder and ionomer (Nafion) in isopropanol [1]. The catalyst layer can be deposited on the gas diffusion layer or on the Nafion membrane.

Catalyst layer deposition parameters

- Pt/C catalysts: 20, 40, 60 Pt wt%
- Suspension: Pt/C + ionomer (Nafion), in isopropanol (1 wt% solids)
- Substrate: Nafion 212R
- Catalyst layer: 0.25 mg_{Pt}/cm^2, 15 wt% ionomer
- Active area: 7 x 7 cm^2
- Electrospray: V_{DC} = 10 kV, T_{subs} = 50 ºC, T_{susp} = 22 ºC, P_{susp} = 0.1 bar

PEMFC mounting and characterisation



The catalyst layers were prepared varying Pt/C ratio (20, 40, and 60 wt%), with constant platinum load (0.25 mgPt/cm²) and 15 wt% ionomer (Nafion). Membranes were coated with the electrosprayed catalyst layer on the cathode side, with a commercial electrode on the anode (BASF, 0.25 mgPt/cm²). Single cell testing was conducted using a specially designed anode flow-field plate with the possibility to insert nine reference electrodes through the back of the gas diffusion layer [2] and eight temperature/relative humidity sensors along the gas channels [3].

PEMFC Mounting

- CCM expansion in 0.5 M H_2SO_4, 22 ºC, 2 h
- Cathode CL: electrosprayed Pt/C, 0.25 mg/cm²
- Cathode GDL: ELAT GDL LT1200W (BASF)
- Anode: ELAT GDE LT250EWALTSI 30wt% Pt/C, 0.25 mg/cm² (BASF)
- **For the "standard" cell:**

Membrane: Nafion 212R
Anode and cathode: both ELAT GDE LT250EWALTSI (BASF) 30wt% Pt/C, 0.25 mg/cm²

Test conditions

- Normal cell operation: 80 ºC, 100% RH, 2:2 stoichiometry, 2 barg backpressure
- Conditioning overnight at 200 mA/cm²
- Polarisation curves obtained at (a) 2 barg and (b) 1 barg backpressures
- ECSA measured at 35 ºC, 100% RH, 1bar_a backpressure.
- Start-stop cycling procedure: 80 ºC, 100% RH, atmospheric pressure, open circuit, anode gas was switched between H_2 and Air at 60 s intervals for 20 cycles

Summary of tested MEAs

Pt/C Catalyst Pt wt%	Nafion wt%	[Pt] mg·cm⁻²	Pt/C	Nafion/C	A_{HUPD} $m^2g_{Pt}^{-1}$	W_{max} W·cm⁻²	R_i(1 kHz) Ohm·cm²
20	15	0.25	0.25	0.21	36	0.45	0.463
40	15	0.25	0.67	0.25	35	0.45	0.519
60	15	0.25	1.50	0.28	43	0.52	0.524
30 (commercial)	30	0.25	0.43	0.61	42	0.45	0.599

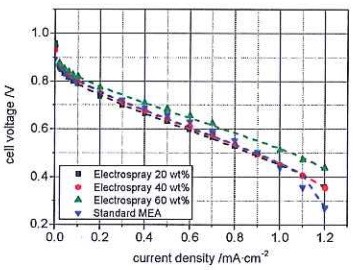
Curves analysis: $V = E^0 - b \cdot \log\frac{i}{i_0} - R_i \cdot i - b \cdot \log\frac{i_L}{i_L - i}$

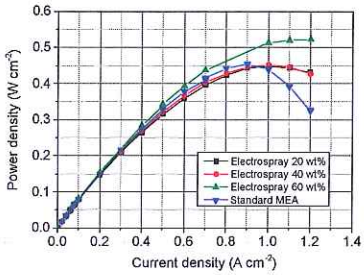
Pt/C Catalyst Pt wt%	E^0 V	A_{HUPD} $m^2g_{Pt}^{-1}$	κ(=A_{Pt}/A_{geom}) (roughness f.)	$i_0 \cdot 10^{-7}$* A·cm⁻²	b V	R_i Ohm·cm²	i_L A·cm⁻²
20	1.17	36	90	1.2	0.060	0.266	1.26
40	1.17	35	88	1.1	0.057	0.275	1.24
60	1.17	43	108	1.4	0.056	0.232	1.26
30(comm.)	1.17	42	105	1.4	0.058	0.273	1.20

* $i_0 = \kappa \cdot 1.3 \cdot 10^{-9}$ A·cm⁻²$_{Pt}$, taken from Eikerling, M. (2006), J. Electrochem. Soc., 153(3), E58-E70.

Polarisation curves

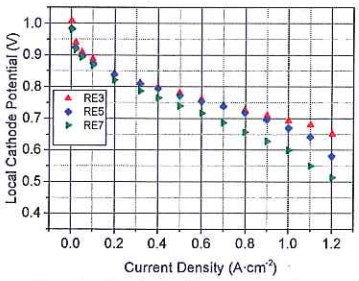
80 °C, 100% RH, 2:2 stoichiometry, 1 bar_g

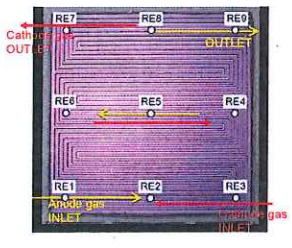




- Pt/C ratio in electrosprayed CL improves the response due to better kinetics (lower b, higher i_0), and lower resistance (R_i).
- Improvement of electrosprayed CL with respect to the commercial electrode must be ascribed to lower resistivity (R_i), larger limiting current (i_L), and better kinetics (b).

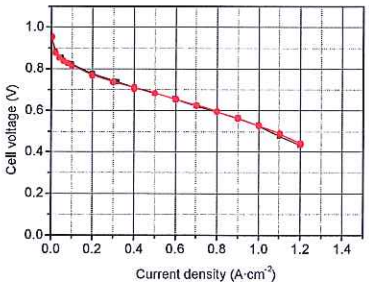
Localised polarisation curves

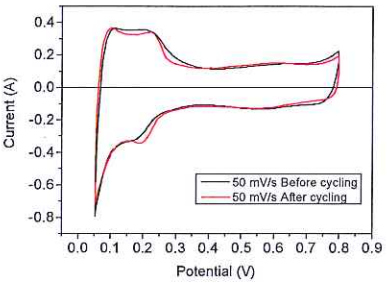




- Localised polarisation curves show a decay along the cathode flowfield path. The decay is more pronounced at high current densities, which reflects oxygen depletion.
- Future work will focus on measurement of localised RH in the gas channels to correlate this with the localised cell performance.

Start-stop cycling





- Electrosprayed CL (60 wt%) performance was not affected by 20 start/stop cycles.
- There was no significant loss of active catalyst area.

Bibliography

[1] A.M. Chaparro, P. Ferreira-Aparicio, M.A. Folgado, A.J. Martín, L. Daza. J. Power Sources, 196 (2011) 4200-4208
[2] E. Brightman, G. Hinds, J. Power Sources, 267 (2014) 160-170
[3] JG. Hinds, M. Stevens, J. Wilkinson, M. de Podesta, S. Bell, J. Power Sources, 186 (2009) 52-57

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