Hydrophobization of PEM Fuel Cell Bipolar Plates Channels with Carbon Based Layers

J.J. Conde , M.A. Folgado, P. Ferreira-Aparicio, A.M. Chaparro

Dep. of Energy, CIEMAT

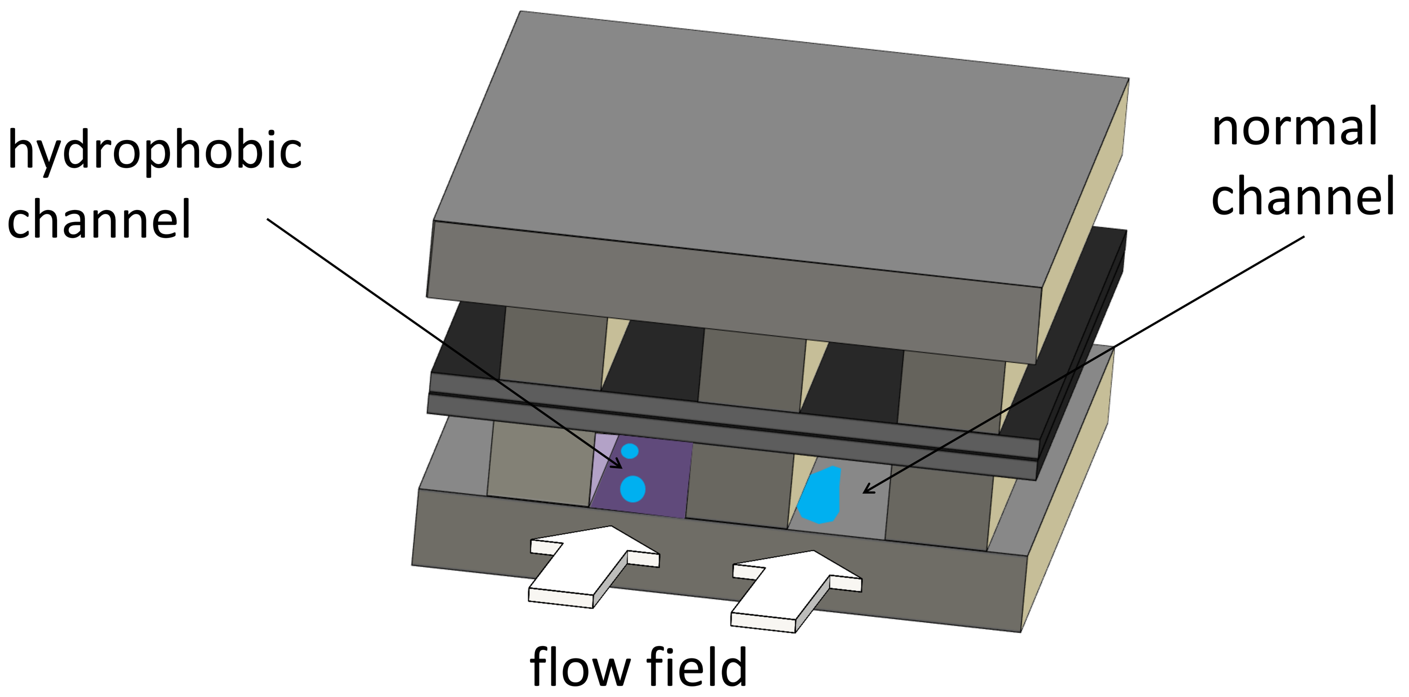
Avda.Complutense ,40. 28040 Madrid (Spain)

Tel.: +34-913460897

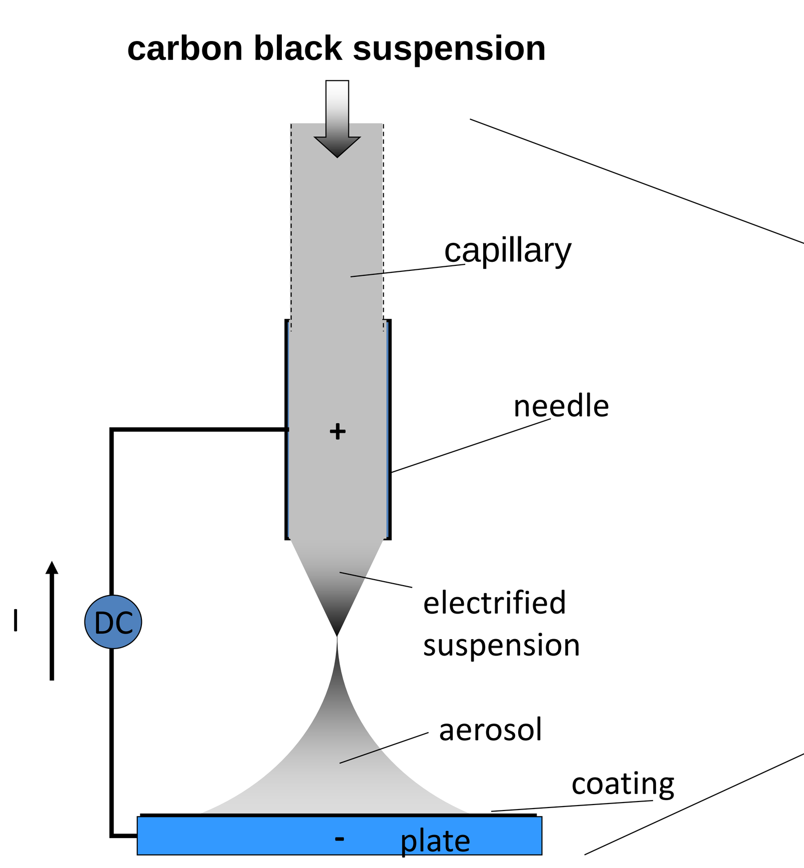
Liquid water elimination from the flow-field may limit the efficiency of proton exchange membrane fuel cells (PEMFC), especially at high current densities. Within the channels of the flow-field, liquid water is dragged by the gas stream and conducted to the outlet of the cell. Its transport and elimination must be fast enough to avoid electrode flooding.

One possibility to accelerate liquid water flow in the channels is by modifying their surface in order to change their hydrophobicity. The hydrophobicity is the capacity of a surface to repeal liquid water, so it must affect drastically liquid water transport in the channels. In this study, a **superhydrophobic carbon-based coating** is applied to the channels of stainless steel bipolar plates. The carbon coating is deposited by means of **electrospray**, which is a method for the deposition of carbon materials that yields layers that are corrosion resistant and superhydrophobic.

Stainless-steel flow field plates have been coated by electrospray in their channels and lands, and only in the channels. The response in single cell is analyzed, and compared with uncoated plates.

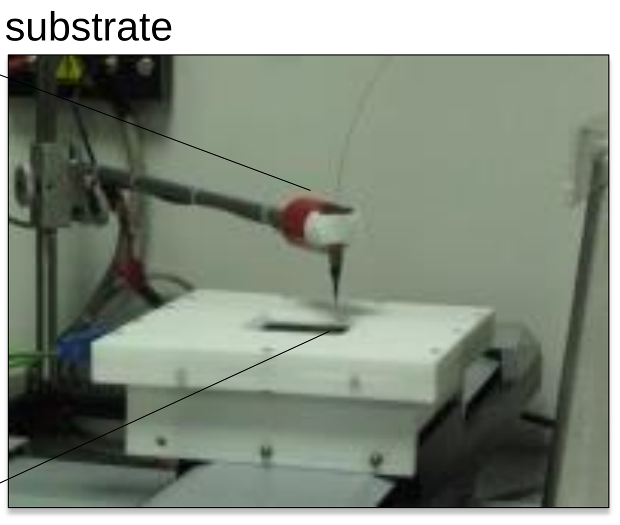


Carbon coating of flow field plates with electrospray

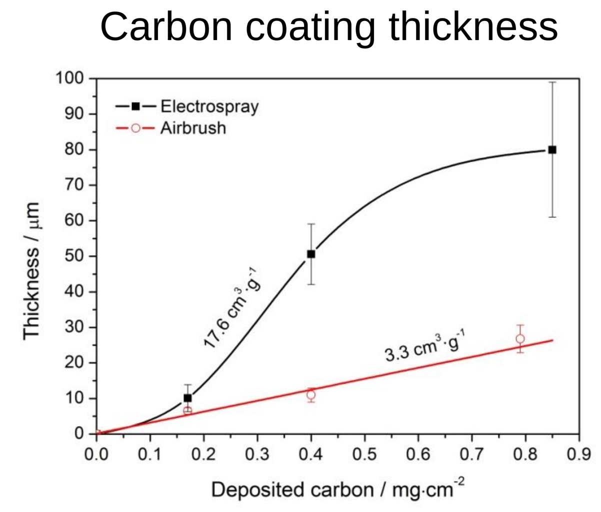


The electrospray deposition process

The electrospray needle and the substrate



Carbon coating thickness

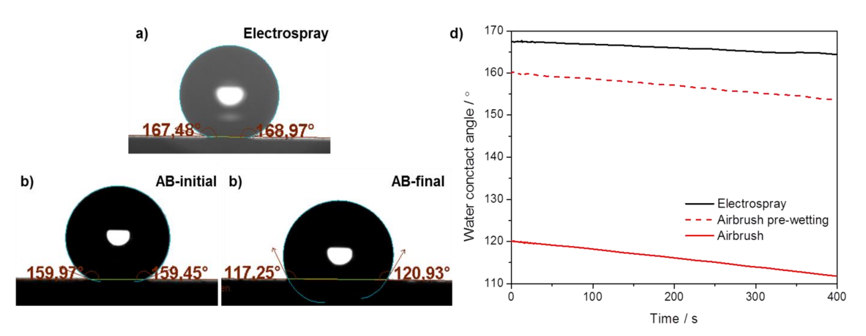


Deposition conditions:

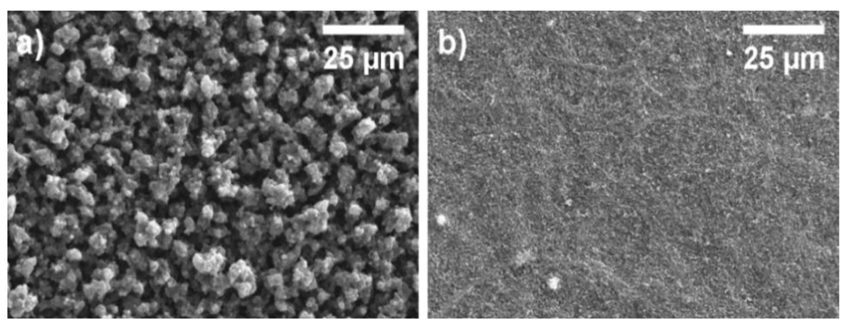
- Inks: carbon black (Vulcan XC-72R, Cabot), Nafion® perfluorinated ion exchange resin (5 wt%, Aldrich), and isopropanol (Panreac)
- Substrate: SS310S plate, polished
- DC voltage: 7kV
- 22ºC ink temp.; 50ºC substrate temp.

Carbon coating characterization

Sessile drop testing



SEM surface morphology

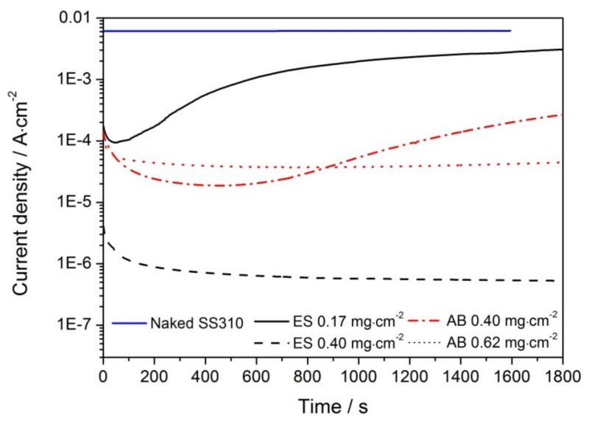


Electrospray Airbrushing

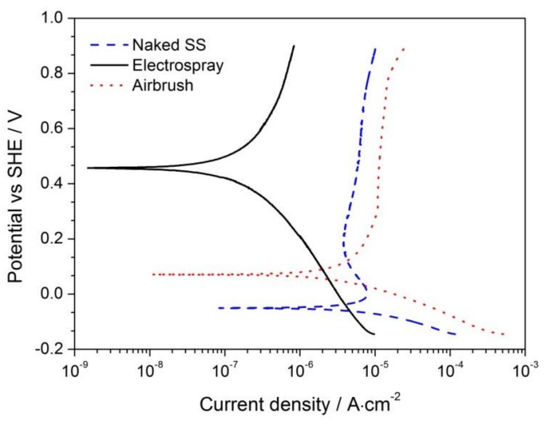
Hydrophobized plate

Two electrochemical corrosion tests of a SS surface coated with carbon black (H_2SO_4, 0.5M, room temperature).

Chronoamperograms (1.35 V vs SHE)



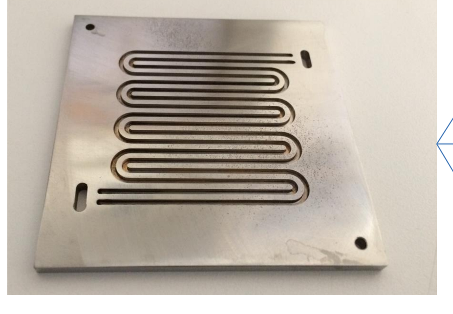
Tafel plots (1mV·s-1)



The electrosprayed carbon layers show a macroporous morphology with superhydrophobic character, persistent after hydrophilic treatments and single cell testing. Layers with 0.4 mgC·cm^{-2} loading are able to protect a metallic surface from electrochemical corrosion in acid liquid contact.

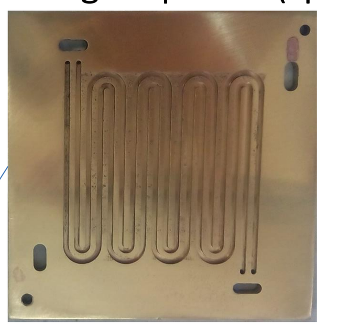
Flow field plates coating

Uncoated plate

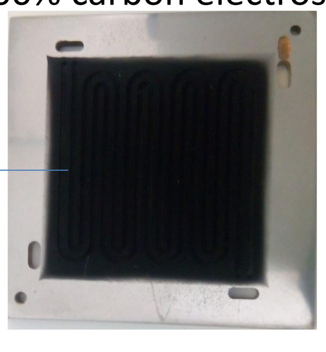


Characteristics:
SS 310S
4x4 cm^2 active area
(6x6 cm^2 total area)
1mmx1mm channel

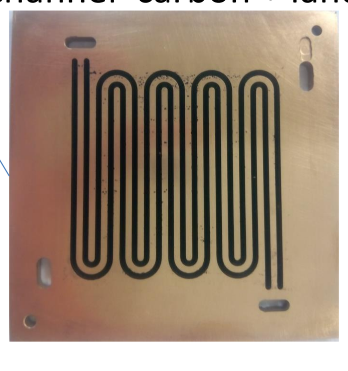
A: 100% gold plated (sputtered)



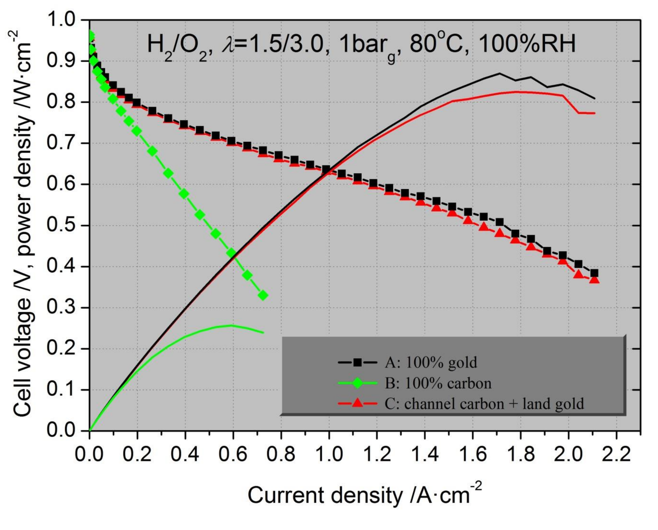
B: 100% carbon electrosprayed

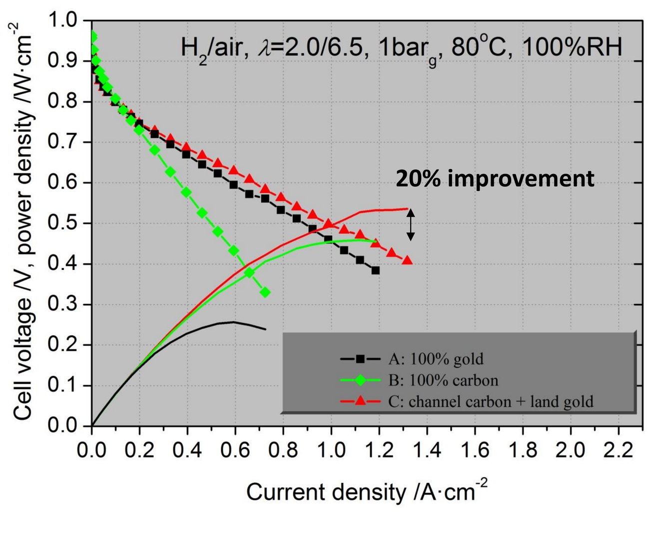


C: channel carbon + land gold



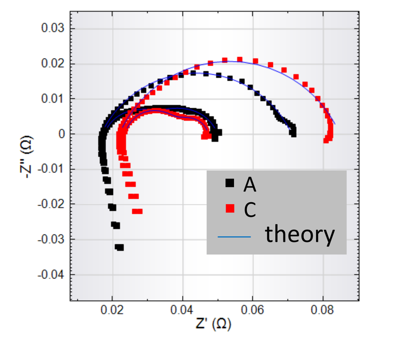
Single cell testing



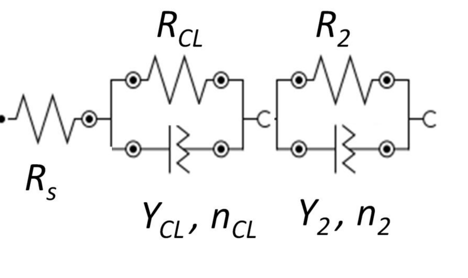


Impedance spectroscopy

H_2/air, λ=2.0/6.5; 1bar$_g$, 80ºC, 100%RH



Equivalent circuit



Impedance analysis

Flow field plating	V_{cell} (V)	R_s (Ohm)	R_{CL} (Ohm)	Y_{CL}($F\cdot s^{n-1}$)	n_{CL}	R_2 (Ohm)	Y_2($F\cdot s^{n-1}$)	n_2
A: 100% gold	0.6	0.018	0.017	5.1	0.79	0.015	0.48	0.80
A: 100% gold	0.8	**0.017**	0.054	0.59	0.73			
C: Channel carbon + land gold	0.6	0.024	**0.009**	4.70	0.88	0.015	0.18	0.89
C: Channel carbon + land gold	0.8	0.022	0.063	0.47	0.74			

A: 100% gold → lower high frequency resistance (R_s)

C: Channel carbon + land gold → lower CL resistance (R_{CL}) at low voltages

Covering the flow field channels with electrosprayed carbon black has a positive effect for cell performance under conditions where larger liquid water amounts must be managed: *j*>0.5A·cm^{-2}, air feeding, 100%RH, 80ºC. Impedance analysis shows that hydrophobized channels (C) increase the high frequency resistance (R_s), and decrease the catalyst layer resistance (R_{CL}), compared with the standard gold plated channels (A). Full carbon coating (B) has a deleterious effect.

Conclusions

- 100% carbon coating increases cell resistance and has a deleterious effect on cell performance.
- Hydrophobization on channels does not affect significantly the performance of the cell if the cathode is fed with oxygen at 80ºC and 100%RH.
- By feeding the cathode with air, under the same temperature and humidification conditions, an improvement is encountered with hydrophobized channels at medium-high current densities, leading to around 20% increase in the maximum power.
- Impedance spectroscopy shows that the improved mass transport in the flow field gives rise to lower catalyst layer resistance.
- Such results appear to indicate that channels hydrophobization improves water transport inside the cell, which is more evident under those conditions when the cell manages the largest amounts of water.

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

E-LiG-E
Efficient and LIGht Energy
FUEL CELL POWER

Portable fuel cell
Pila de combustible portátil
ENE2015-70417-P
http://projects.ciemat.es/es/web/elige/

EUROPEAN FUEL CELL FORUM

EFCF 2019
Low-Temperature
Fuel Cells, Electrolysers & H_2 Processing
Fundamentals and Engineering Design
23rd Conference in Series with Exhibition
2– 5 July 2019, Lucerne, Switzerland