In-situ electrochemical characterization of lab scale PCFCs

Editorial

The 1st of December 2011 marked the start of the METPROCELL project: **Innovative fabrication routes and materials for METal and anode supported PROton conducting fuel CELLs.** It has been a collaborative project funded by the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) where 8 partners work together to develop a new generation of intermediate temperature fuel cells based on the Proton Conducting Fuel Cell technology. The METPROCELL project lasted until 31th of May 2015.

This report summarizes the activities performed in the frame of Work Package 4 in relation to the electrochemical characterization of the developed Proton Conducting Fuel Cells (PCFCs) at lab scale.

Dr. - Ing. Maria Parco
TECNALIA. Spain
METPROCELL Project Manager

Content

1. Introduction

This report summarizes the work performed in the frame of the Task 4.6 of METPROCELL in relation to the characterization of lab scale cells. The objectives of the METPROCELL project for lab-scale cells were the following:

- To achieve more than 400 mW/cm^2, 0.6V at 600°C.
- To assess the long term stability (target > 500h) of the developed PC cells under relevant service conditions.

Two strategies have been followed for the manufacture of the substrates for **the anode-supported configuration**: pressing and tape-casting. The anodes elaborated by pressing have been elaborated by CNRS-ICGM, those fabricated by tape casting have been produced by EIFER. Both BCZY and $BaZr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1}O_{3-\delta}$ as electrolyte and BSCF, SSC and SmBSCF as cathode material have been used. The deposition of electrolytes and cathode materials has been performed by Wet Powder Spraying (at ICGM) or by screen printing (at either EIFER or ICMCB) (see "METPROCELL-WP4-Development of anode supported PCFC button cells by wet chemical routes", also available under http://www.metprocell.eu). **Table 1** summarizes the button cell configurations elaborated by wet chemical routes based on the hydrogen electrode supported configuration.

Table 1: Configuration of the hydrogen electrode supported button scale cells tested in Task 4.6.

Ref.	Cathode layer	Electrolyte	Anode support	Cell Geometry
C1	BSCF-BCZY (WPS)	BCZY-ZnO WPS	BCZY-NiO Pressing	Φ:30 mm
C2	BSCF/BSCF-BCZY (WPS)	BCZY-ZnO WPS	BCZY-NiO Pressing	Φ:30 mm
C3	BSCF/BSCF-BCZYYb (WPS)	BCZYYb-ZnO WPS	BCZYNiO Pressing	Φ:30 mm
C4	SSC/SSC-BCZYYb (WPS)	BCZY-ZnO WPS	BCZY - NiO Tape casting	30*30 mm
C5	SmBSCF/ SmBSCF-BCZYYb (WPS)	BCZY-ZnO WPS	BCZY - NiO Tape casting	30*30 mm
C6	BSCF/BSCF-BCZY Screen-printing	BCZY-ZnO Screen-printing	BCZY-NiO Tape-casting	4.5x4,5cm² Φ:16 mm
C7,C8	BSCF/BSCF-BCZY Screen-printing	BCZY-ZnO Screen-printing	BCZY-NiO Tape-casting	4,5x4,5cm² Φ:16 mm
C9	PrN/PrN-BCZY Screen-printing	BCZY-ZnO Screen-printing	BCZY-NiO Tape-casting	4,5x4,5cm² Φ:16 mm

Concerning the **metal-supported configuration**, porous ferritic stainless steel (Iron Chromium steels) supports developed by HOGANAS in the frame of Task 4.1 have been used (see "METPROCELL-WP4-Development of porous metal supports", also available under http://www.metprocell.eu). The hydrogen electrode and the electrolyte layer have been deposited by means of a thermal spray technology [a proprietary High Velocity Oxy/Air-Fuel (HVOF/HVAF) spray technology from TECNALIA]. The air electrode has been deposited by wet chemical routes based on receipt formulations and deposition procedures optimized on the hydrogen electrode cell configuration. **Table 2** summarizes the description of the cells elaborated by such a combination of optimized thermal spray procedures and wet chemical routes.

Table 2: Configuration of the metal supported button scale cells tested in Task 4.6.

Reference	6-11	6-12	7-4	7-5	11B-2	11B-1
Support geometry/ thickness	Φ: 28 mm/ 600μm (active area: 2 cm²)					
Anode powder (particle size)	BCYZ/NiO 40/60wt.% cermet (d90~35 μm)		Powder blend of BCZY-ZnO (d90~45 μm) and NiO 40/60wt.%		Powder Blend of BCZY-ZnO (+25 -40 μm) and NiO 40/60wt.%	
Anode thickness	~55μm	~50μm	~55μm	~55μm	~45μm	~45μm
Electrolyte powder (particle size)	BCZY –ZnO (d90~45 μm)		BCZY –ZnO (d90~45 μm)		BCZY –ZnO (<25 μm)	
Electrolyte thickness	~25μm	~40μm	~35μm	~40μm	~25m	~30μm
Deposition process for anode/electrolyte (Manufacturer)	HVOF/HVAF (TECNALIA)					
Cathode (Manufacturer)	BSCF-BCZY (70:30) – BSCF / (ICMCB)			SmBSCF – BCZYb (70:30) / SmBSCF (ICGM)		
Process /cathode	Screen printing			Wet Powder Spraying		

2. In-situ electrochemical test results

The performances and electrical characteristics of **anode-supported** cells presented in **Table 3** are very promising and reach the objectives of the METPROCELL project. Moreover, it was found that the combination of the different wet chemical routes, i.e. tape-casting/screen-printing or tape-casting/WPS techniques are suitable for the elaboration of larger size PCFC.

In relation to the development of **metal supported cells** by combining thermal spraying and wet chemical routes, in the best case a max. power density of only 43 $mW.cm^{-2}$ at 650°C

(OCV: 0.98 V; ASR_{tot}: 5.5 Ω.cm²) was reached. At the light of the collected results, it can be concluded that the electrolyte structure in the as-sprayed condition is not dense enough to achieve a high cell performance. Moreover, a further decrease of the functional electrolyte thickness down to 10-15 μm, would be mandatory to reach ohmic resistance values comparable to those measured on the hydrogen supported cells. The implementation of a suitable post thermal treatment could potentially lead to fully dense electrolyte layers, but significant efforts are still needed to optimize the processing route and decrease the functional thickness of the electrolyte.

Table 3: Performances and electrical characteristics of hydrogen electrode supported cells at 600°C.

Ref.	OCV (V)	P_{max} (mW/cm^2)	ASR_{Ohm} (EIS) (Ω.cm^2)	ASR_{pol} (EIS) (Ω.cm^2)	ASR_{tot} (EIS) (Ω.cm^2)	ASR_{tot} (j-V) (Ω.cm^2)
C1	1.015	140	1.14	0.49	1.63	1.92
C2	1.097	190	0.67	0.42	1.09	0.73
C3	1.105	418	0.303	0.275	0.578	0.62
C4	1,134	372	0.470	0.479	0.891	0.93
C5	1.148	513	0.340	0.221	0.562	0.60
C6	1.09	165	0.4	0.8	1.2	1.6
C7	1.11	144	1.52	0.55	2.07	2.19
C8	1.10	150	1.20	0.67	1.87	2.07
C9	1.08	116	1.23	1.38	1.60	2.41

Project details

Start date: 2011-12-01
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Project cost: 3.4 million euro

Project Coordinator and Scientific Responsible:

Dr. -Ing. María PARCO
Fundación Tecnalia Research & Innovation
maria.parco@tecnalia.com

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