GRANT AGREEMENT: **N° 213389**
Project Acronym: **IDEAL-Cell**
Project Title: **Innovative Dual mEmbrAne fueL-Cell**

Funding Scheme: **Collaborative project**
Small of medium-scale focused research project

Periodic consortium report Y3 (D1.3)

IDEAL-Cell project

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Logo of the project:

1. Publishable summary

The IDEAL-Cell® project aims at developing a new dual membrane fuel cell concept operating at intermediate temperature (< 700 °C, ideally 600 °C). This patented innovative system, combining the benefits of state-of-the-art devices (PCFC and SOFC) while evading their disadvantages, consists in assembling the anodic compartment of a PCFC (anode/electrolyte couple; figure 1a) and the cathode part of a SOFC (cathode/electrolyte couple; figure 1b) through a central membrane wherein water is formed, by combination of H^+ and O^{2-} ions, and immediately evacuated (figure 1c).

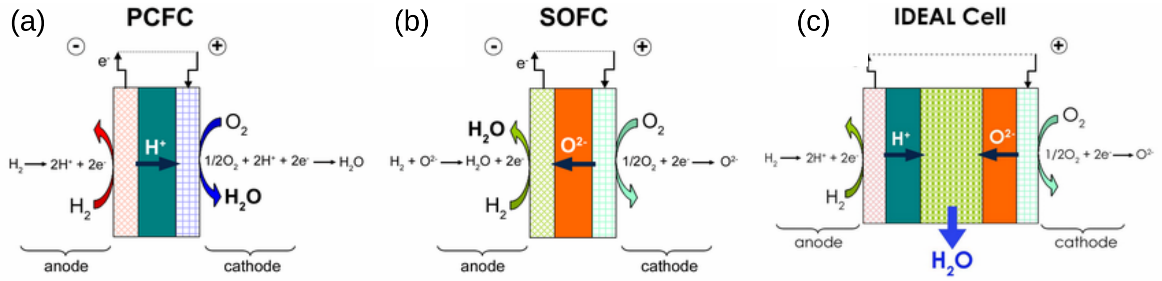

Figure 1. Schematic representation of (a) a PCFC, (b) a PCFC and (c) the IDEAL-Cell.

The validity of the IDEAL-Cell concept has been experimentally proven after two years of research via the fulfilment of the four proof of concept criteria established in collaboration with the Advisory Board (1/ a stable value of the Open Circuit Voltage, 2/ a stable V/I polarization curve, 3/ a specific impedance fingerprint giving evidence for the appearance of water, 4/ a clear and direct evidence of water formation within the central membrane when an electrical current flows through the cell) on dedicated Proof of Concept Pt/BCY15/CM/YDC15/Pt samples.

A new electrochemical model has also been developed in order to describe the operation of the cell and it shows that the most important electrical losses are caused by over potentials occurring in the central membrane: this latter is therefore the limiting component for optimal operation of the device (in standard SOFCs and PCFCs, the limiting components are the electrodes). However, the performances of this membrane can be optimized by modifying some morphological parameters, among them the percolation of the solid and gaseous phases, tortuosity, active triple phase boundaries (TPBs) segments length, permeability... In year 3, the first attempts to integrate polymer grids to create a channelled porosity within the central membrane have been made with highly encouraging results. 3D tomography and CFD calculation on these structures were achieved.

After the proof of the concept, during the third year of the project optimisation works carried out on components geometry and microstructure led to a progressive enhancement of the electrochemical performances from 1 $mWcm^{-2}$ to 45 $mWcm^{-2}$ within a few months (figure 2). These performances were obtained on ± 2mm thick samples, which suggest a very high potential for improvement.

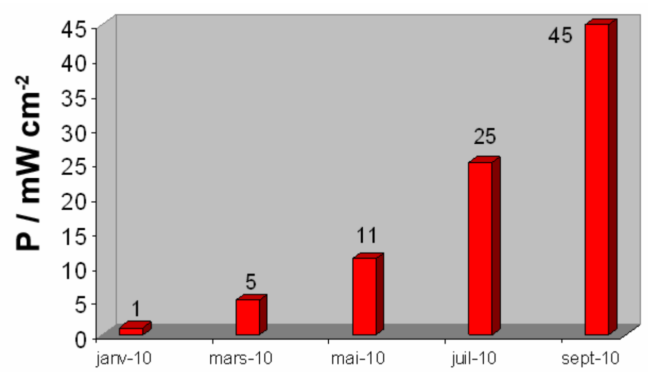

Figure 2. Improvement of the power density via continuous optimisation of components.

Excellent performances for the cathode compartment were achieved, thanks to well-tailored tape casting and plasma spraying processes. The oxygen conductivity of YDC15 in the central membrane was measured in realistic condition by feeding a porous CM sample with oxygen. The reactivity tests performed within this task did not reveal any physico-chemical incompatibility between components.

Oxygen conductivity was detected in BCY15 when fed with oxygen. At 600 °C, it appears experimentally that the oxygen and proton conductivities of BCY15 were equivalent. This led us to considerably improve the original concept by the use of BCY15 as a mixed conductor, for both oxygen and proton electrolytes and for the central membrane; as a result, the cell can be made of a single material, simplifying drastically the shaping process, and opening the route for improved performances (i.e. the TPBs become surfaces instead of segments). This improved concept is being patented.

The anode performances have been continuously improved and chemical instabilities at interfaces are being solved. The proton conduction was estimated by feeding a CM sample with hydrogen. In addition to the proof of the concept, activities were focused on the electrochemical modelling aiming at describing the electrical behaviour of IDEAL-Cell. The macro- and micro-kinetic models were fed with morphological parameters extracted from the analysis of 3D microtomography images. Physical properties, such as the Darcy's permeability and effective ionic conductivities, could be predicted using fast Fourier transforms based computation on the 3D images. Extensive works have been achieved and anticipated within activities dedicated to interconnects, among them the fabrication of a highly innovative tester (RLT = Real Life Tester) dedicated to the electrical characterisation of different interconnect materials, cell components and cells in real operating conditions with 3 independent chambers.

Regarding dissemination, the design and the implementation of the public and internal IDEAL-Cell websites were continuously updated. The success in the management of knowledge was hold to the efficient tools, (i) internal convention for samples, (ii) publications register that allow for exchange of information within the consortium. The lists of conference presentations, publications and in coming events were created.

→ address of the external website: www.ideal-cell.eu/
→ address of the internal website: www.ideal-cell-team.eu/