Project Acronym: **IDEAL-Cell**
Project Title: **Innovative Dual mEmbrAne fueL-Cell**

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Small of medium-scale focused research project

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TECHNICAL REPORT on the Dual Cell potential performances (D4.1)

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IDEAL-Cell project

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Summary

This technical report intends to reflect the potentialities of the dual IDEAL-Cell performances, which are obviously totally subordinated to the proof of the IDEAL-Cell concept, and to the quality of the oxygen and hydrogen compartments (deliverables 2.1 and 3.1 respectively).

Simplified Proof of Concept (PoC) samples (see figure 1 in section 3.1.) were fabricated by different processing routes and electrochemically characterized; they all verify the Proof of Concept criteria (i/ stable OCV; ii/ stable V/I polarization curve; iii/ complex impedance signature for water formation; iv/ detection and quantification of the water produced in the central membrane) established in agreement with our Advisory Board. At present, the best performances measured at 600 °C on a BCY15 ($BaCe_{0.85}Y_{0.15}O_{3-\delta}$) self-supported PoC sample (750 µm thick and 21 mm of diameter) are an OCV equal to 1.03 V and an operating power density of almost P = 5 mW cm^{-2} (respectively 2 and 1 orders of magnitude less than standard SOFC and experimental PCFC). In addition, a “negative resistance”, interpreted as the fingerprint of water formation, has been observed by complex impedance spectroscopy, and the amount of water produced in the central membrane was measured and found to be in the range of the value calculated from experimental data on the tested PoC cells.

An original mathematical model, involving electrochemical, thermodynamical, macro and micro-kinetical aspects has been developed to describe the general electrical behaviour of IDEAL-Cell (polarization and electrochemical performances in steady state and dynamic conditions with varying operation parameters), disclosing that its electrical performances are particularly controlled by the efficiency of the central membrane. The recorded polarization curve fits well the calculated one when experimental data from tested PoC samples are introduced, hence validating the model; as expected from the concept itself, the comparison between the mathematical model and the experimental data shows that the electrode contribution to the overpotential is highly reduced as compared to SOFC and PCFC. On account of millimetre to centimetre thicknesses of the PoC cells, the measured external current is low, in the range of 1.0 to 10 µA, but the possibilities of optimizing the central membrane morphology and microstructure are tremendous (standard SOFC electrolytes are 100 to 300 times thinner, and the IDEAL-Cell central membrane microstructure is far from being optimized yet). Routes for monitoring the optimization of the central membrane are identified, especially *via* the highly relevant outcomes from the high resolution X-ray microtomography measurements (carried out at ESRF) and the modelling (a CFD code was developed to describe the flow of water within different morphologies of the central membrane).

Reactivity tests give evidence of chemical reactions taking place at cell temperature operation (600-700 °C) between the LSCF48 ($La_{0.60}Sr_{0.40}Co_{0.20}Fe_{0.80}O_{3-\delta}$) cathode material and the Cr-rich interconnect metals tested (Crofer 22 APU and JS3 from Thyssen Krupp, AL453 from Allegheny Ludlum), and during sintering (at 1350 °C) within the NiO-BCY15 anode precursor. The first reaction involves the inter-diffusion of La and Cr, which can be limited by appropriate coating or pro-oxidizing treatment of interconnect. The second reaction originates from the decomposition of BCY15 at BY15/NiO interfaces, leading mainly to the continuous precipitation of resistive Y_2O_3 particles impairing significantly the anode performances. Routes for limiting the reactivity at the anode (addition of BaO and ZnO, decrease of the sintering temperature, incorporation of In_2O_3 in the BCY15 lattice) are under experimental evaluation.

This deliverable reports also the first results for the shaping and testing of a new IDEAL-Cell design based on a metallic central membrane, and presents the first complete IDEAL-Cell obtained i/ by tape casting, ii/ by a sequence of cold pressing and tape casting, iii/ by tape casting on a Ni-foam supported anode.