PEMFC based on platinum group metal free structured cathodes (PEGASUS)

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Fuel cells, as a highly efficient energy conversion technology, and hydrogen, as a clean energy carrier, have a great potential to reduce carbon dioxide emissions and to reduce dependence on mainly imported hydrocarbons. Fuel cells and hydrogen can also contribute to economic growth and to a strong European competitiveness, thus creating employment in Europe.

Proton exchange membrane fuel cell (PEMFC) is the fuel cell predilection technology for automotive applications with a large deployment horizon by 2025-2030 [1]. However, the increasing use of fuel cell electrical vehicles (FCEV) is expected to lead to a quickly growing demand for Platinum Group Metals (PGMs) because fuel cells vehicles require a multiple of the PGM amounts needed for conventional cars, between 30 and $50g_{Pt}$ for a 100 kW full power stack. PGM production is not only itself related to some negative environmental impacts (e.g. through the use of fossil-fuel energy for mining and metallurgical plants), but also raises questions of long-term availability due to the limitation of reserves and Europe's economic dependence on the countries of the materials' origin. In order to avoid future barriers for development and dissemination of FCH technologies, their materials demand and the related issues should hence be considered early enough in order to develop strategies to react on the changing markets and the new challenges – as well as the opportunities – they are posing.

Besides, durability and cost are also primary challenges to fuel cell commercialization. Fuel cell systems must compete with automotive internal combustion engines (ICEs) and other alternative technologies. The performance and durability of FCEV have already been proved with car integrating high content of Pt based catalyst. To be also considered with incumbent and future competing technologies, the cost of automotive fuel cell systems needs to be competitive, both on the Total Cost of Ownership (TCO) and on initial cost basis (CAPEX). These cost targets must be achieved while ensuring that systems provide the performance and durability already demonstrated by high cost FCEV. One of the key issue lies on the fact that the cost of PEMFCs is driven by the use of Platinum (Pt), a very effective hydrogen oxidation and oxygen reduction catalyst, which represents an estimated 30% of PEMFC. In addition, Pt is sensitive to contamination from impurities in hydrogen and certain air contaminants, which impose the use of high H_2 purity and filter at the airside of the PEMFC system.

Hence, it is of high strategic importance that the transition to a next-generation PEMFC using Platinum Group Metals-free (PGM-free) catalysts is made as quickly as possible to ensure Europe's competitive position and to reduce market pressure on the use of scarce noble metals. While decreasing Pt loading in MEAs has been considered as an intermediary step, the ultimate industrial goal will be to manufacture PEMFC stacks for transport application with Non-PGM catalysts, and with performance and durability comparable to the targets defined currently with Pt.

In that perspective, PEGASUS project is exploring a promising route towards the removal of Pt and other critical raw materials (CRM) from PEMFC and their replacement by non-critical elements & structures enabling efficient and stable electro-catalysis conditions for an appropriate use as Pt-alternative competitive cathodic catalysts. The overall aim of this project is to bring up the experimental proof of concept for novel catalysts materials & structures with some specific quantitative technical and economic targets. The five following underlying objectives are core to the project and will support the validation of the catalyst materials & structures at single cell scale with a focus on the cathode side:

Objectives 1 & 2 - High performance and durable MEA using non-PGM catalysts-based cathode.

Non-PGM catalyst materials & structures will be delivered with sufficiently improved performance (Objective 1) and durability (Objective 2) compared to the current State-of-Art of non-PGM catalysts. These catalyst solutions will be produced in sufficient and reproducible quantities for dedicated use in cathodes and subsequent integration into MEAs prior to assembling into test single cells. Test in single cells, compliant with EU harmonized test protocols [2], will sustain the experimental proof of concept validating the actual potential of novel catalysts in representative operational PEMFC conditions.

Objective 3 - Low cost MEA using non-PGM catalysts-based cathode.

Novel non-PGM catalysts materials & structures and associated processes will be delivered offering an integrated cost competitive solution at the stack level while compromising favorably with performance and durability aspects addressed in Objectives 1 & 2. Energy efficiency, materials efficiency, process repeatability and up-scalability will be shown at each process step demonstrating an overall production worthy route in comparison to PGM based conventional routes.

Objective 4 - Robust test protocols for catalysts/cathodes screening.

A test protocol update to existing protocols (cell break-in, cell conditioning, polarization curve testing, FC-DLC and MEA specifications [2]) will be set up taking advantage of and creating synergies across the most sensitive and selective characterization tools & methods currently available for fuel cell materials and components assessment. This protocol will give predictions of the functional performances of catalysts and active layers (current density at a given voltage; volumetric performance of both catalyst and AL) while also providing accurate estimations for key properties at the scale of the critical elementary mechanisms governing mass and charge transports (e.g. O_2/H_2O diffusion, water condensation, e^-/H^+ conduction). As an outcome, it will deliver the simplest path towards an efficient assessment of the intrinsic activity of catalysts, opening the door to systematic catalysts and cathodes benchmark and faster PEMFC development cycles.

Objective 5 - Understanding of catalysts/cathodes degradation and prevention/mitigation strategies through a MEA design-driven approach

PEGASUS is a knowledge driven project targeting performance and durability improvements of non-PGM catalyst-based cathodes (Objectives 1 & 2) through an in-depth understanding of actual degradation roots, mechanisms, kinetics and inter-dependencies. In that sense, the project will particularly focus on transport mechanisms inside the active layer in order to tailor appropriate materials & structures solutions preventing or mitigating mass/charges losses during operation and with operation time. The correlation between materials and transport conditions associated to the in-depth understanding of underlying mechanisms and limitations will open the door to a MEA design-driven approach to reach the best cathode/MEA performance and durability.

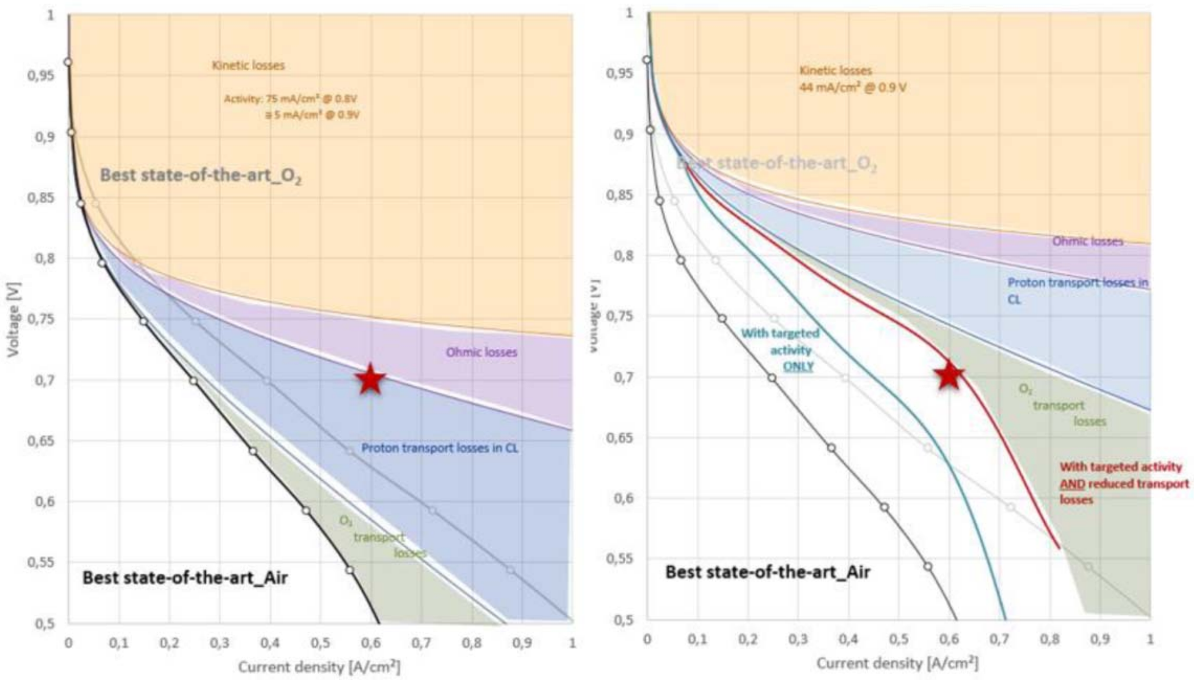

Figure 1. (Left) Performance with decomposition of the contribution of the different losses of the best State-of-the-Art (SoA) non-PGM catalyst with O_2 and Air vs PEGASUS objectives and (Right) PEGASUS non-PGM catalyst with targeted activity in Air: (blue) ~100 μm thick SoA non-PGM CL and (red) with reduced transport losses in ~50μm thick CL. 80°C, 100%HR.

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