## Next Steps

CRESCENDO partners are working to further improve cathode non-PGM catalyst activity and stability and then to implement the most prospective materials in improved catalyst layers to reach the project targets. While the CO tolerance of non-PGM anode catalysts is known, we also aim to demonstrate their $H_2S$ tolerance and implement most prospective CRESCENDO anode and cathode catalysts in an all-non-PGM MEA. Our further study of the relation between site density, turnover frequency, catalyst physical properties and activity will support and accelerate catalyst development.

## Events

The international conference Electrolysis and Fuel Cells Discussions 2019 (EFCD 2019), dedicated to all aspects of the science and technology of ultra-low and PGM-free catalysts for fuel cells and electrolysers, was held on 15th-18th September 2019 in La Grande Motte, France. EFCD 2019 was jointly organised with the European project, CREATE.

2019 EFCD

*www.efcd2019.eu*

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## Partners

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Horizon 2020
European Union funding
for Research & Innovation

**Annual Newsletter**
September 2019 / Issue #1

# CRESCENDO

Critical Raw material ElectrocatalystS
replaCement ENabling Designed
pOst-2020 PEMFC

**CRESCENDO IS A 3 YEAR EU SUPPORTED PROGRAMME TO DEVELOP HIGHLY ACTIVE AND STABLE NON-PGM ELECTROCATALYSTS FOR AUTOMOTIVE PEMFC AND TO RE-DESIGN THE CATHODE CATALYST LAYER**

## Edito

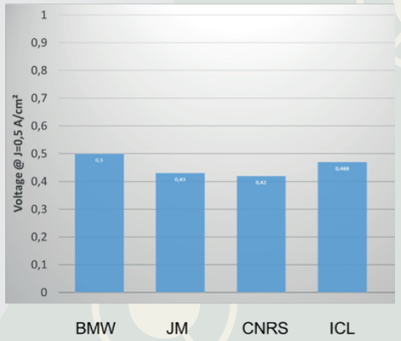
**CRESCENDO** aims to develop highly active, stable and durable electrocatalysts using non-platinum group metals (non-PGM) for the PEMFC cathode and includes the re-design of the cathode catalyst layer, with a project target power density of 0.42 W/cm² at 0.7 V in single cells. **CRESCENDO** also has the objective to develop non-PGM or ultra-low PGM anode catalysts with greater tolerance to CO and $H_2S$ than current low loading Pt anodes. The development of innovative PEMFC materials having significantly lower platinum contents will avoid dependency on the supply of critical raw materials, consolidate Europe's competitive position, and reduce market pressure on the use of scarce noble metals. Provided that the non-PGM based MEAs are able to provide the high power density at high current density required by FCEVs, the resulting cost savings will be game-changing.

The very ambitious fuel cell power density and durability targets of **CRESCENDO** are far beyond the state of the art. The project team is tackling, head-on, the crucial bottlenecks in non-PGM fuel cell catalysis by developing new methodologies for the determination of catalyst descriptors hitherto not considered, in parallel to new catalyst development, new approaches to catalyst stabilisation and cathode catalyst layer re-design specific to non-PGM catalysts.

You are invited to read some highlights of the first months of **CRESCENDO** in this newsletter.

# Main Achievments

## WP2 - *Ex situ* electrochemical characterisation of commercial and state of the art PGM-free catalysts



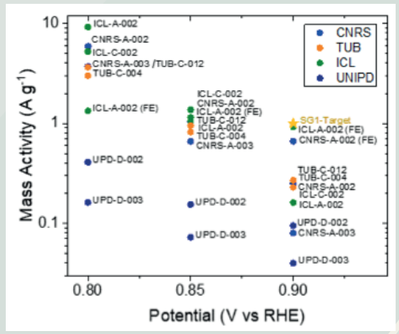

BMW together with project partners from JMFC, CNRS and ICL have tested and evaluated the performance of commercial PGM-free CCMs under various operating conditions. The results are in good agreement between different partners, despite the use of different testing hardware. The commercial PGM-free CCMs exhibit performance of 0.15 A/cm² at 0,418 V under one of the project's set operation conditions. CRESCENDO's target is to reach 0.7 V at 600 mA/cm².

*Performance comparison of commercial PGM-free CCMs at 0.5 A/cm² under 100% RH and 2.3 bara outlet under $H_2$ and $O_2$ stoichiometry of 2.0 and 9.5 respectively.*

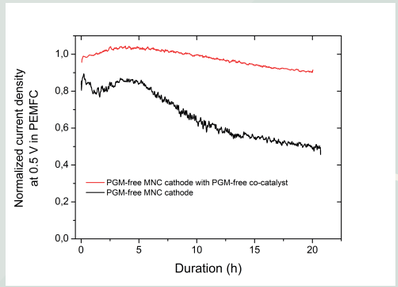
## WP3

Following complementary synthesis strategies at partners TUB, CNRS, ICL and UNIPD, newly prepared catalysts were evaluated using rotating ring disc, floating electrode, and catalyst coated membrane techniques. Currently the highest activity observed (0.92 A/g at 0.90 V RHE) is considered to reach the mid-term project target of 1 A/g at 0.90 V RHE. Although all materials have iron-nitrogen moieties as the catalytically active species, their active site density and/or their turn over frequency differ in characteristic ways depending on their synthesis and processing. Different limiting factors and materials parameters were identified that control the site density and turn over frequency for each catalyst type. This learning is being used to guide a more rational, knowledge-driven development pathway of PGM-free catalysts.

Emphasis is being placed on the development and utilisation of robust diagnostic tools to assess the number of catalytically active surface sites and the intrinsic turn-over frequency of the catalysts - important performance descriptors that have not been available to date, yet are critical for a understanding-driven development of PGM-free catalysts. The best performing catalysts will be down selected and transferred to other WPs for further development and deployment in electrode layers.




*New CRESCENDO PGM free catalysts from project partners and their performance in RRDE testing. FE: Floating electrode*



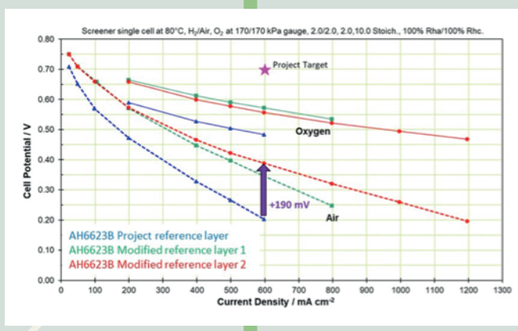

*PGM-free MNC cathode with PGM-free co-catalyst*

## WP4

In WP4, the consortium optimised existing methods and established novel diagnostic tools for accelerated durability testing. Screening of sacrificial and regenerative scavengers for reactive oxygen species has provided probably the first demonstration of the rational stabilisation of PGM-free M-NC catalyst by a PGM-free co-catalyst, and potentially opens up a rich landscape of PGM-free co-catalysts with improved stability during PEMFC operation. Model surface studies shed new light on the stabilisation of Fe-NC catalysts by ultra-low amounts of platinum.

## WP5 - Advanced cathode layer design for non-PGM catalysts

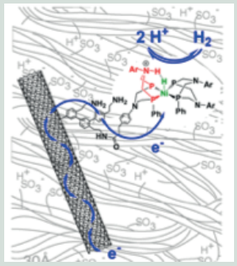
To enable realistic application of PGM-free fuel cells for automotive applications, an operating project target of 0.7 V at 600 mA/cm² has been defined in CRESCENDO. Efforts in WP5 are aimed at the integration of PGM-free catalysts into catalyst layers and the characterisation of these layers in 50 cm² single cells. At present, cathode catalysts layers with PGM-free catalysts are nearly an order of magnitude thicker than state of the art Pt/C catalysts layers (i.e. 100 µm vs 10 µm). Not surprisingly, such thick layers have been found to suffer from high mass transport losses even at moderate current densities. To improve the performance of the PGM-free cathode layers at high current densities, research activities in WP5 are focused on understanding and then reducing mass transport losses in real life hardware with the help of in situ diagnostic protocols and complementary ex situ characterisation.




Testing in 50 cm² single fuel cells showed that the performance of the project Fe-NC reference catalyst on air was, initially, 500 mV lower than the ultimate project target of 0.7 V at 0.6 A/cm². In-cell diagnostics were complemented by ex situ characterisation, which showed that the reference catalyst formed layers with low pore volume and pronounced hydrophilicity, compared to a conventional Pt/C layer. By optimisation of the ink and catalyst layer properties, significant improvements to the layer performance were achieved and the operating voltage at 600 mA/cm² on air was increased by 190 mV (61%), exceeding the objective of a 50% reduction in losses.

## WP6 - Integration of bioinspired nickel complexes in anode catalyst layer

In WP6, CEA, UniPD and ICL are building on previous results* to integrate $H_2$-oxidising molecular nickel catalysts inspired from the active site of hydrogenase enzymes in the anode catalytic layer. Multi-wall carbon nanotubes are tested as electrode material. The working plan includes the optimisation of the grafting process thanks to the use of graphenic acid, so as to increase site density, the determination of intrinsic catalytic turnover of each nickel site, the benchmarking of the performance of this material against a standard catalyst provided by Johnson Matthey and the combination of such bio-inspired nanomaterials with Nafion and other additives to improve mass transport within the catalyst layer.




** Gentil et al. Angew. Chem. Int. Ed. 2017, 56, 1845-49*