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Elucidating the Degradation Mechanisms of Mesoporous Carbon-Supported Platinum Catalysts in Practical PEMFC Operations

~Contributing to the Widespread Adoption of Stationary Fuel Cells and Fuel Cell Vehicles by Advancing Both Catalyst Activity and Durability~

N.E. CHEMCAT CORPORATION (Head office : Minato-ku, TOKYO, President: Susumu Endo) has elucidated the degradation mechanism of platinum catalysts supported on mesoporous carbon (MPC) during the startup and shutdown (SU/SD) of polymer electrolyte fuel cells (PEMFCs), which involves the air shutdown, confinement, and introduction. By implementing the upper potential limitation control through micro-power generation that leverages the characteristics of MPC, we have identified its mitigation mechanism of degradation. This method enables MPC catalyst to maintain a performance equivalent to or better than that of industry-standard products (using porous supports) over the long term. Results of this research were published in the American Chemical Society (ACS) journal "ACS Applied Energy Materials" on April 27.

MPC is a carbon material that has recently attracted attention as a support for a cathode catalyst in high-power PEMFCs due to its high specific surface area and structural controllability with an abundant mesoporous structure. To date, research on their durability has been limited primarily to conventional potential-sweep accelerated durability tests. However, the degradation behaviour and mechanisms of MPC under actual operating conditions have not been sufficiently investigated. We focused on the unique structural properties of MPC electrocatalysts to evaluate their durability, particularly during the SU/SD process.

In this study, our research team focused on the relationship between carbon dioxide generation and cell voltage under air-start/stop conditions, employing an analytical method that directly captures the gas emitted from the Membrane Electrode Assembly (MEA) outlet. Furthermore, using three-dimensional electron microscopy (STEM tomography), the team separately analysed platinum nanoparticles located inside and outside the catalyst support, thereby elucidating the degradation behavior and detailed mechanisms under actual operating conditions. By maintaining precise control of the operating voltage under 0.88 V via micro-power generation, the team confirmed the effectiveness of degradation suppression, which is a technique viable for practical system control. This approach was found to promote air consumption during shutdown while lowering the oxidation level of the platinum, thereby suppressing both carbon corrosion and platinum dissolution.

This research provides critical insights into electrode catalyst and fuel cell system design to extend fuel cell lifespan. These findings offer guidance for optimizing conditions toward the practical application of MPC platinum catalysts and for the innovation of next-generation materials.

For more details on this research, please refer to the following link.

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■**Paper Title :** " Degradation Mechanism and Mitigation Strategy of Mesoporous Carbon-Supported Pt

Catalysts during Realistic Startup and Air Confinement Shutdown in Polymer Electrolyte Fuel Cells"

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■Details of the paper (PDF version)

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This research is the result of joint research between N.E. CHEMCAT CORPORATION and Professor Makoto Uchida and his research group at Yamanashi University.

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For PEMFCs, achieving both high performance and durability is of paramount importance. MPC catalysts have attracted significant attention as promising materials for high-efficiency systems due to their high activity.

This study presents three significant findings:

- 1) The study evaluated the durability of Pt/MPC catalysts under realistic SU/SD conditions involving power generation and air confinement.
- 2) Comprehensive analysis, involving time-resolved monitoring of CO₂ generation and Pt dissolution revealed that MPC catalyst particularly exhibits severe performance degradation. This study found that MPC undergoes carbon corrosion, specifically in region with restricted proton access under SU/SD conditions, leading not only to mass transport issues but also to significant Pt particle growth.
- 3) To mitigate this degradation phenomenon, the study demonstrated that micro-power generation promotes oxygen consumption and controls the upper potential which suppresses Pt oxidation and mitigates carbon corrosion, thereby effectively decreases performance loss.

This study has identified key challenges regarding the long-term operation of catalysts using porous supports and has provided practical strategies for suppressing degradation in real-world environments. It offers significant insights for future designs of catalysts and catalyst layers.

■ About N.E. CHEMCAT CORPORATION:

N.E. CHEMCAT CORPORATION is engaged in the development, manufacturing, and distribution of chemical catalysts, auto exhaust catalysts, and fuel cell catalysts, and recovery of precious metal catalysts.

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