Realization of Environmentally-Friendly High-Performance Three-Way Catalyst

Clarification of two major mechanisms of catalysts for automotive exhaust purification

Achievements

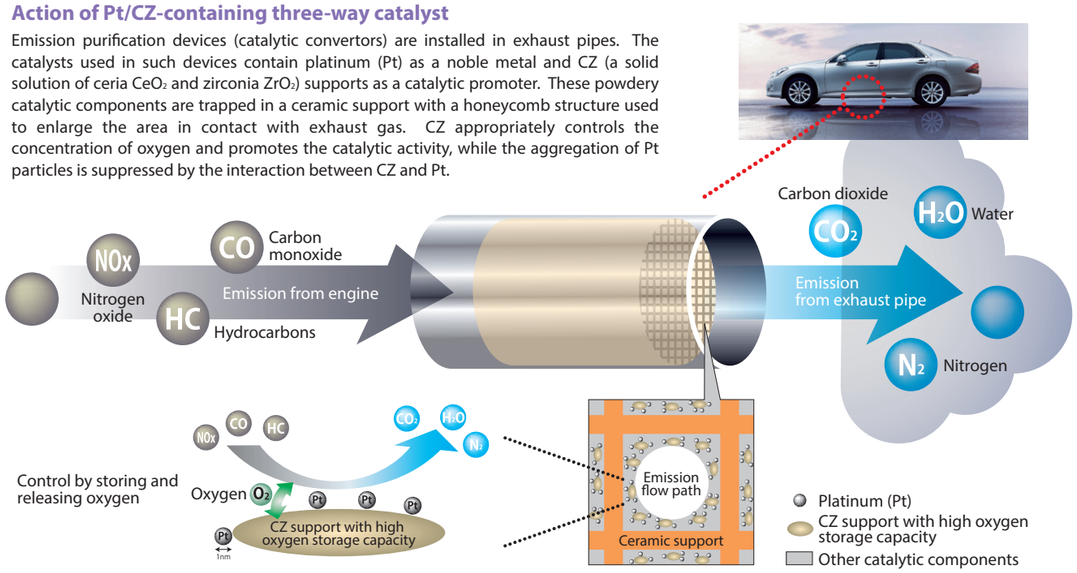
- Clarification of the **mechanism behind the storage and release of oxygen** to optimize the activities of **three-way catalysts*** for the purification of automotive exhaust gas
- Elucidation of the **aggregation suppression mechanism of catalytic noble-metal particles** to provide long-lasting catalytic activities
- Contribution to environmental cleanup by the installation of high-performance three-way catalysts developed using these analyses in gas-powered cars

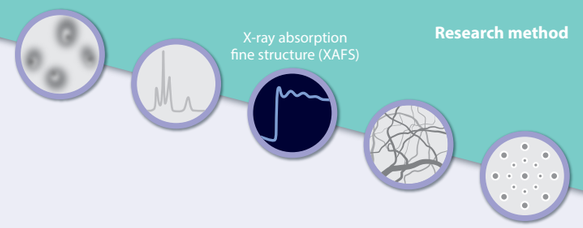
R&D facility: Toyota Motor Corporation and Toyota Central R&D Labs., Inc.

***Three-way catalyst:** Harmful components in vehicular exhaust gas are oxidized or reduced by the action of catalysts and thus the exhaust gas is purified. Three-way catalysts promote the simultaneous detoxification of three harmful components, that is, carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxide (NOx), and are used most frequently in gasoline-powered vehicles. Three-way catalysts comprise noble metals causing catalytic reactions, supports for dispersing these noble metal particles in the nanometer scale, and catalytic promoters assisting the noble-metal-induced catalytic reactions.

Action of Pt/CZ-containing three-way catalyst

Emission purification devices (catalytic convertors) are installed in exhaust pipes. The catalysts used in such devices contain platinum (Pt) as a noble metal and CZ (a solid solution of ceria CeO_2 and zirconia ZrO_2) supports as a catalytic promoter. These powdery catalytic components are trapped in a ceramic support with a honeycomb structure used to enlarge the area in contact with exhaust gas. CZ appropriately controls the concentration of oxygen and promotes the catalytic activity, while the aggregation of Pt particles is suppressed by the interaction between CZ and Pt.





Role of SPring-8

Background

The components of exhaust gas from automobiles are continuously changing; hence, to appropriately control the concentration of oxygen in accordance with the changing components, materials with a high capability to promptly store and release oxygen are required. CZ supports were developed as a material with such a function. However, the factors behind the improvement in the function were unknown.

Moreover, in the process of development, it was revealed that the aggregation of platinum (Pt) particles was suppressed by combining CZ supports with Pt, and thus the catalytic activity was maintained. We needed atomic-level analysis to clarify the mechanism behind this result.

Results

A high-brilliance, high-energy X-ray must be used to examine the structure of CZ supports in detail because their constituents are heavy elements. The results of the XAFS analysis at SPring-8 revealed that the ability of CZ supports to store and release oxygen varies depending on the arrangement of heavy metal atoms.

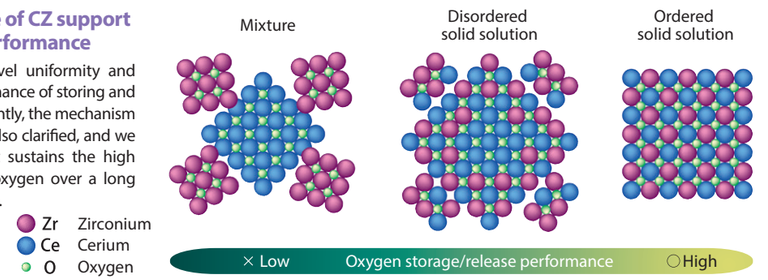
Moreover, the catalysts containing both CZ supports and Pt form Pt-O-Ce bonds when exposed to high-temperature exhaust gas, preventing the aggregation of Pt particles. The mechanism underlying this suppression of aggregation was clarified by XAFS analysis.

From these analyses, we succeeded in improving the catalytic materials containing Pt/CZ and in realizing a high-performance three-way catalyst.

Publication: Y. Nagai et al.; Catalysis Today **74**, 225-234 (2002) Y. Nagai et al.; Journal of Catalysis **242** (1), 103-109 (2006)
T. Tanabe et al.; Journal of Catalysis **257** (1), 117-124 (2008)

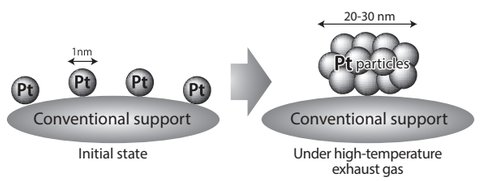
Relationship between structure of CZ support and oxygen storage/release performance

The significant effect of the atomic-level uniformity and configuration of Ce and Zr on the performance of storing and releasing oxygen was clarified. Subsequently, the mechanism of the deterioration of CZ supports was also clarified, and we elucidated a CZ support structure that sustains the high performance of storing and releasing oxygen over a long time (joint research with Kyoto University).



Suppression mechanism of catalytic noble-metal particle aggregation

When conventional catalysts are exposed to high-temperature gas, their Pt particles aggregate and grow. As a result, the surface area of the particles decreases, and hence the area in contact with exhaust gas decreases, causing a deterioration of the purification performance.



When Pt/CZ catalysts are exposed to high-temperature gas, Pt-O-Ce bonds are formed by the interaction between Pt and CZ, preventing the aggregation of Pt particles. Under normal conditions, catalytic reactions are induced when the bonds break, resulting in the lasting activity of the catalysts.