Realization of Intelligent Catalyst for Automotive-Emissions Control
Clarification of self-regenerating mechanism to maintain catalytic activity

Achievements

- Atomic-level clarification of the mechanism of "intelligent catalysts*" - a catalytic precious metal renews itself using special ceramic materials
- Substantial reduction of precious metal usage by intelligent catalysts using precious metals, such as palladium, platinum, and rhodium
- Contribution to environmental purification and resource saving from the installation of intelligent catalysts on more than 4 million automobiles as of July 2008

R&D facility: Daihatsu Motor Co., Ltd., and Japan Atomic Energy Agency

*Intelligent catalyst: Automotive catalysts deteriorate as a result of a decrease in the active surface area of the precious metals, and this is caused by the growth of metal grains under the inherent redox environment of exhaust gases at high temperatures. We developed self-regenerating catalysts in which precious metals were coordinated as ions into special ceramic crystals (a perovskite oxide). The self-regenerating catalysts, which suppress the grain growth of precious metals, are based on the repeated movement of the precious metals in and out of perovskite crystal between a solid solution and metallic nanoparticles during the natural changes in the red condition. That is, the newly developed catalysts have a self-regenerating function to change their structure in accordance with the environment. Intelligent catalysts were thus named to reflect this function.

Background

The performance of automobile catalysts deteriorates with increasing mileage. Therefore, an excess amount of precious metals is required to maintain the catalytic performance throughout the life of an automobile; but from the viewpoint of over-consumption and supply problems of precious metals, it is necessary to suppress the deterioration of automobile catalysts.

We developed intelligent catalysts with a self-regenerating function using a new concept. However, conventional methods were insufficient to clarify the mechanism at an atomic level.

The crystalline structure of the perovskite oxide was examined in detail using the high-brilliance X-ray at SPring-8, which is suitable for measuring the properties of precious metals. As a result, it was clarified that precious metal ions repeatedly move in and out of the crystals depending on the state of the exhaust gases, thereby maintaining sufficient catalytic performance.

We developed a number of self-regenerating ceramic materials by applying this technology, and succeeded in substantially reducing the use of precious metals. This technology is attracting attention worldwide as a new means of solving environmental and resource-related problems at the same time.

Mechanism of self-regeneration of intelligent catalyst

Precious metal ions are coordinated in the form of a perovskite oxide precipitate from the crystals and form nanosized precious metal particles under an oxygen-deficient condition. The ions diffuse into the crystals under an excess-oxygen condition, and the particles return to an atomic size. Intelligent catalysts maintain their high catalytic activity by restoring the size of particles through this mechanism.

Role of SPring-8

The gases exhausted from automobiles repeatedly change its state between oxidizing and reducing states several times per second. Catalysts are exposed to temperatures as high as 1000°C under such an atmosphere. Precious metal particles are gradually enlarged in the presence of conventional catalysts. In contrast, precious metal particles can maintain their highly active fine size in the presence of intelligent catalysts.

Change of precious metal catalyst in exhaust gases

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Results

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