Effect of precious metals and NOx storage materials on hydrogen reduction of stored NOx on millisecond time scale

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1. Introduction

To protect the global environment, a worldwide reduction in CO₂ emissions is required. High fuel-efficiency lean-burn engine technology is a promising method for alleviating the CO₂ emission problem in automotive applications. However, the emissions from lean-burn engines include NOx production under oxygen-rich conditions, and the reduction of NOx is extremely difficult under such conditions. On the basis of the considerable research conducted on various methods, a NOx storage and reduction (NSR) catalyst for automobiles was put into practical use in 1994 by the Toyota Motor Corporation [1,2].

An NSR catalyst has the ability to reduce NOx, even under oxygen-excess conditions, using two operations: first is the storage of NOx using alkali or alkali earth materials under oxygen-rich conditions, and second is the reduction of stored NOx under oxygen-poor conditions produced by a short-period, rich pulse of reducing gases. The alternate repetition of these storage and reduction operations results in the reduction of NOx to nitrogen. To develop efficient NSR techniques with low fuel cost, it is necessary to investigate the reaction mechanisms involved. It is suggested that the reduction of stored NOx is the rate limiting step in the overall NSR process at low temperature [3]. The evaluation of the rate at which stored NOx is reduced requires measurement of the time profiles of the products produced during the reduction process. However, it is difficult to measure these products because the reaction is usually very fast and the main product is gaseous nitrogen, which is also a normal emission product from engines and is used as a model gas in laboratory tests.

We previously reported the comparison results of NOx reduction processes with Pt/Ba/Al₂O₃ and Pt/K/Al₂O₃ catalysts by analyzing the NOx reduction using a temporal analysis of products (TAP) reactor [4,5]. The TAP method was developed by Gleaves et al. [6] and is widely recognized as an effective method for transient reaction analysis [7]. From our analysis, we found that the reduction rate of stored NOx using Pt/K/Al₂O₃ was faster than that using Pt/Ba/Al₂O₃, and the ratio of N₂ to NH₃ produced in the reaction was affected by different catalysts. The NOx storage process in potassium has also been studied [8–11]. Potassium-containing materials show strong potential as NOx storage materials (NSMs) and as a NOx selective-reduction catalyst [12].

Many scientists have studied the effect of precious metals (PMs) on NSR activity in order to improve the performance of NSR catalysts. In particular, Abdullahamid et al. studied the effect of different reducing agents (H₂, CO, C₃H₆, and C₃H₈) on the reduction of stored...