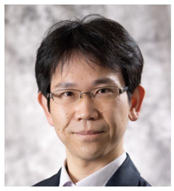
Exhaust gas treatment, Wastewater treatment

Development of environmental catalysts for effective decomposition of harmful organic compounds



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Abstract

Novel environmental catalysts have been created to decompose harmful organic compounds, such as VOCs (e.g. toluene) and phenolic compounds, into non-toxic carbon dioxide and water. In these catalysts, oxidation was facilitated by the active oxygen supply from the promoter, which were developed from the viewpoint of the solid state chemistry field. By using the developed catalyst, gaseous toluene was completely oxidized at the temperature as low as 100°C, where a typical catalyst required 170°C. In the liquid-phase, furthermore, the developed catalyst completely removed phenol under the moderate conditions of the atmospheric open-air system at 80°C, while typical catalysts needed sever conditions of 10-50 atm at 140-170°C.

Background & Results

To date, several methods have been utilized for the removal of harmful organic compounds. Among them, the catalytic decomposition is regarded as a sustainable system, because harmful compounds can be catalytically oxidized into non-toxic carbon dioxide and water. However, typical catalysts (e.g. Pt/Al_2O_3) required high temperatures and/or high pressures (e.g., 170°C for toluene combustion in gas-phase, and 10-50 atm and 140-170°C for phenol oxidation in liquid-phase).

Although a general method to obtain high activity is the control of dispersion and surface area of an activator (Pt, etc.), this study focuses on the introduction of the promoter, which can supply active oxygen species from inside the lattice toward the activator (Fig. 1). CeO_2-ZrO_2 solid solution is a famous promoter in automotive exhaust catalyst; however, it works at elevated temperatures of ca. 800°C. Thus, it is important to develop novel promoters which can operate at lower temperatures. From the viewpoint of the solid state chemistry field, in this study, NiO was introduced into the CeO_2-ZrO_2 lattice to form the oxide ion vacancy for oxide ion migration. As a result, the oxygen supply ability successfully improved, and the Pt/CeO_2-ZrO_2-NiO/Al_2O_3 catalyst exhibited the high activity for toluene combustion compared to the Pt/CeO_2-ZrO_2/Al_2O_3 case (Fig. 2). By using Pt/CeO_2-ZrO_2-NiO/Al_2O_3, toluene was completely oxidized at the temperature as low as 100°C, which is lower than the typical catalyst (170°C for complete toluene combustion).

For the liquid-phase oxidation, SnO_2 was introduced into the CeO_2-ZrO_2 lattice, because the Sn ion can hold two kinds of valence states (Sn^{4+} and Sn^{2+}), resulting in the high oxygen supply ability. By using CeO_2-ZrO_2-SnO_2 as a promoter, phenol was completely removed under the moderate conditions of the atmospheric open-air system at 80°C, where the typical catalysts required 10-50 atm and 140-170°C.

Significance of the research and Future perspective

Organic compounds including VOCs and phenolic compounds have been widely used as organic solvents and raw materials for production of resin, etc.; however, they have to be removed from exhaust gas and wastewater due to their harmful effects for human and the environment. The novel catalysts, created in this study, showed considerably high activities compared to the typical catalysts. These catalysts are expected to apply the advanced equipment having simple, low-cost, and sustainable system.

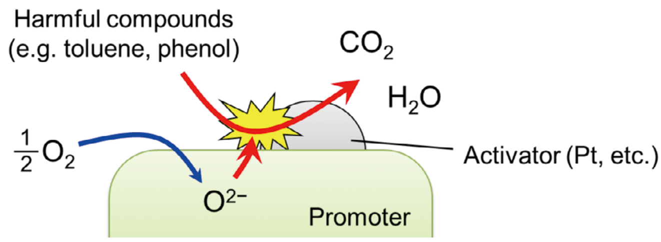

Figure 1. Schematic illustration of decomposition of harmful organic compounds using oxygen supply from the promoter toward the activator.

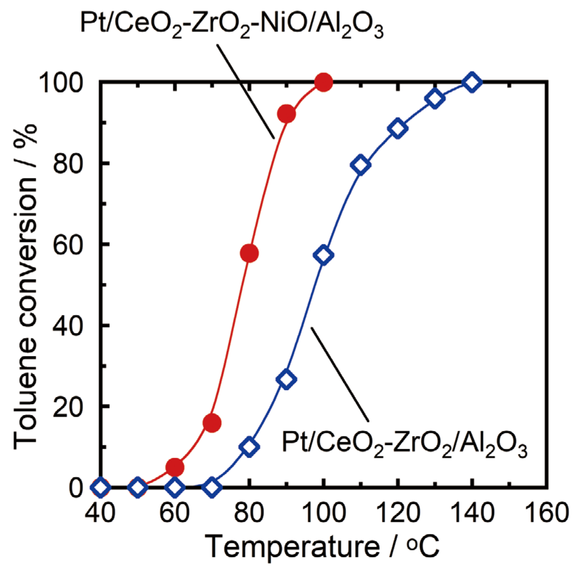

Figure 2. Temperature dependence of toluene conversion over Pt/CeO_2-ZrO_2-NiO/Al_2O_3 and Pt/CeO_2-ZrO_2/Al_2O_3.

Patent

Treatise
Jeong, Minchan; Nunotani, Naoyoshi; Imanaka, Nobuhito et al. Introduction of NiO in Pt/CeO_2-ZrO_2/γ-Al_2O_3 Catalysts for Removing Toluene in Indoor Air. Materials Letters. 2017, 208, p. 43-45, doi: 10.1016/j.matlet.2017.05.048
Abdul Rohman Supandi; Nunotani, Naoyoshi; Imanaka, Nobuhito. Complete Phenol Removal in Liquid-phase under Moderate Condition over Pt/CeO_2-ZrO_2-SnO_2/ZrO_2/SBA-16 Catalysts. Functional Materials Letters. 2020, 13, p. 2050030: 1-4, doi: 10.1142/S1793604720500307

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Keyword environmental catalysts, volatile organic compounds, rare earths