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A comparative study of bulk and 3DOM-structured Co_3O_4, $Eu_{0.6}Sr_{0.4}FeO_3$, and $Co_3O_4/Eu_{0.6}Sr_{0.4}FeO_3$: Preparation, characterization, and catalytic activities for toluene combustion

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A B S T R A C T

Three-dimensionally ordered macroporous (3DOM) and bulk Co_3O_4, $Eu_{0.6}Sr_{0.4}FeO_3$ (ESFO), and 3 wt% $Co_3O_4/Eu_{0.6}Sr_{0.4}FeO_3$ ($3Co_3O_4$/ESFO) were fabricated using the PMMA-templating (3DOM-Co_3O_4 and 3DOM-ESFO), citric acid-assisted hydrothermal (Co_3O_4-bulk and ESFO-bulk), and incipient wetness impregnation ($3Co_3O_4$/3DOM-ESFO and $3Co_3O_4$/ESFO-bulk) methods, respectively. Physicochemical properties of these materials were characterized by means of various techniques, and their catalytic activities were evaluated for toluene combustion. Compared to the nonporous Co_3O_4 and ESFO samples, the 3DOM-Co_3O_4, 3DOM-ESFO, and $3Co_3O_4$/3DOM-ESFO samples exhibited higher oxygen adspecies concentrations and better low-temperature reducibility. The $3Co_3O_4$/3DOM-ESFO sample showed the best catalytic activity for toluene combustion, giving the $T_{50\%}$ and $T_{90\%}$ of 251 and 269 °C at 20,000 mL/(g h), respectively. The apparent activation energies of these samples were in the range of 72–88 kJ/mol. We believe that the higher oxygen adspecies concentration, better low-temperature reducibility, and synergistic action between Co_3O_4 and 3DOM-structured ESFO were responsible for the excellent catalytic performance of $3Co_3O_4$/3DOM-ESFO.

1. Introduction

Most of volatile organic compounds (VOCs) emitted from industrial and transportation activities are harmful to the environment and human health. Catalytic combustion is generally regarded as one of the most effective and economic alternatives for the abatement of VOCs [1,2], in which supported noble metals and transition metal oxides are the most commonly used catalysts in the literature [2–4]. In spite of high performance for the oxidation of various VOCs, applications of noble metal (e.g., Pt, Pd, and Rh [5])-based catalysts are restricted due to their high cost, low thermal stability, easy sintering, and tendency to poisoning [3,6,7]. Therefore, it can make much sense to develop cheap and efficient catalytic materials. As potential alternatives of noble metals in the catalytic oxidation of VOCs, simple transition metal oxides (MO_x) and perovskite-type oxides (ABO_3) have been gained much attention [8,9]. It has been generally accepted that catalytic performance of metal oxides is widely accepted to be associated with factors, such as surface area, pore structure, oxygen nonstoichiometry, and reducibility [10]. Porous metal oxide materials possess unique physicochemical properties that favor the heterogeneous catalytic reactions. It is often reported that there may be possible synergistic actions between MO_x and ABO_3. For instance, the stability and catalytic activity of $LaMnO_3$ could be enhanced in the presence of excess MnO_x attached on the perovskite for the removal of automotive exhaust pollutants [11]. The investigations on the MO_x/ABO_3 catalysts, such as $Co_3O_4/LaCoO_3$ [12], $Co_3O_4/Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3$ [13], $Co_3O_4/LaFe_{0.7}Cu_{0.3}O_3$ [14], and $Fe_2O_3/La_{0.6}Sr_{0.4}Co_{0.8}Fe_{0.2}O_3$ [15,16], have been reported. To the best of our knowledge, however, there have been no reports related to the three-dimensionally ordered macroporous (3DOM) ABO_3-supported MO_x catalysts (i.e., MO_x/3DOM-ABO_3) for the combustion of VOCs.

Previously, our group investigated the fabrication and catalytic properties of three-dimensionally (3D) ordered mesoporous Co_3O_4 (surface area = 118–121 m^2/g) [17] and Cr_2O_3 (surface area = 73–106 m^2/g) [18], 3D ordered macroporous (3DOM) Fe_2O_3 (surface area = 32–46 m^2/g) [19], 3DOM $LaMnO_3$

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