

Rational design of monolithic catalyst for CO oxidation

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Abstract

The significant diffusional resistance offered by packed-bed reactors has severe limitation for industrial deployment of powder CO oxidation catalysts by decoupling observed activity from intrinsic kinetics. To overcome this engineering limitation, Ag/Ce_xTi_{1-x}O₂ (AgCeTi-x, x = 0.3, 0.5, and 0.7) monolithic catalysts was rationally designed by loading the catalyst through novel solvothermal method on a cordierite monolithic substrate. The Ce/Ti molar ratio was systematically varied to interrogate its influence on Ce³⁺ concentration, oxygen vacancy density, and Ag⁺/Ag⁰ concentration, as characterized by XRD, BET, FE-SEM, and XPS analysis. Solid-solution formation of powder sample without phase segregation was confirmed from XRD analysis and unique broccoli-like structure with Ag as floret and metal oxide as stem is evident for AgCeTi-0.7 sample from FE-SEM and EDX analysis. On loading the catalyst to monolithic cordierite structure, the major diffraction peaks correspond to cordierite phase along with the corresponding morphological modification was observed. Both powder and monolithic catalysts were compared for the CO oxidation performance and the performance inverse is observed for Ce-rich (x=0.7) and Ti-rich (x=0.3) samples with x=0.3 (T_{50%} = 100 °C) sample showing better result among powder sample and x=0.7 (T_{50%} = 87 °C) shows better result among the monolithic samples. Significant improvement in monolithic catalyst performance could be related to overcoming of diffusional resistance despite having lower O_β vacant oxygen and lesser dual-site Ag⁺/Ag⁰ ratios. This work demonstrates that material composition along with reactor architecture must be co-optimized as an inseparable design unit for efficient catalyst performance.

Keywords: Ag nanomaterials, Bimetallic support, monolith, CO oxidation, MOF-derived catalyst, One-pot solvothermal method