Effect of Support Materials on the Performance of Ru-Based Catalysts for CO_2 Methanation

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Abstract

Carbon dioxide (CO_2) methanation has attracted significant attention as an effective technology for CO_2 utilization and renewable energy storage through the production of synthetic natural gas. Ruthenium (Ru)-based catalysts are considered among the most promising systems for this reaction due to their excellent hydrogenation ability, high activity at relatively low temperatures, strong resistance to deactivation, and ability to promote efficient CO_2 activation and methane formation.

However, the catalytic performance of Ru strongly depends on the nature and properties of the support material, which influence metal dispersion, electronic interactions, surface acidity/basicity, and CO_2 adsorption capacity. In this study, Ru catalysts supported on SiO_2, CeO_2, and ZrO_2 were investigated for CO_2 methanation performance. The results demonstrated a significant support effect on catalytic activity and selectivity. Among the studied systems, Ru@ZrO_2 exhibited outstanding catalytic behavior, achieving almost 100% CO_2 conversion and 100% CH_4 selectivity at 225 °C. The superior performance of Ru@ZrO_2 is attributed to favorable metal–support interactions, enhanced CO_2 activation, and improved dispersion of active Ru species. These findings highlight the crucial role of support engineering in designing highly efficient Ru-based catalysts for low-temperature CO_2 methanation.

Keywords

Ru (ruthenium), CO_2 methanation, supported catalysts, ZrO_2 support, metal–support interaction, CO_2 conversion, synthetic natural gas.