Hydrogen Production from the Steam and Dry Reforming of Methane: the Role of Ceria as Catalyst, Support, and Promoter

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Cerium Oxide or ceria (CeO_2) was found to be useful for the steam and dry reforming of methane. By applying this material as support and promoter, the catalyst provides significantly higher reforming reactivity and excellent resistance toward carbon deposition compared to conventional Ni/Al_2O_3. These enhancements are due to the high redox property of CeO_2. During the reforming processes, in addition to the reaction on metallic catalyst surface, the redox reactions between the gaseous components in the system and the lattice oxygen (O_x) take place on ceria surface. Among these reactions, the rapid redox reactions of carbon compounds such as CH_4, and CO with lattice oxygen can prevent the formation of carbon species from the methane decomposition and Boudard reactions even at low inlet steam and carbon dioxide concentrations.

Surprisingly, nanocomposite high surface area ceria (CeO_2 (HSA)), synthesized by a surfactant-assisted approach, was observed to be an excellent catalyst for both steam and dry reforming reactions producing H_2 and CO under Solid Oxide Fuel Cells (SOFCs) conditions. Regarding the intrinsic reaction kinetics over CeO_2 (HSA), the reforming rate over this catalyst is proportional to the methane partial pressure and the operating temperature. Carbon dioxide presents weak positive impact on the methane conversion, whereas steam concentration seems to be independent of the rate. The adding of carbon monoxide and hydrogen inhibit the reforming rate. The activation energies and reforming rates under the same methane concentration for CeO_2 toward the dry reforming are almost equal to the steam reforming. This result suggests the similar reaction mechanisms for both the steam reforming and the dry reforming over CeO_2; i.e., the dry reforming rate is governed by the slow reaction of adsorbed methane, or surface hydrocarbon species, with oxygen in CeO_2, and a rapid gas-solid reaction between CO_2 and CeO_2 to replenish the oxygen.