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Sustainable hydrogen production via dry reforming of biogas using NiO-M_xO_y-Al_2O_3 catalysts: Enhanced performance and low coke deposition

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Abstract

Sustainable hydrogen production as a new energy vector is of fundamental importance for the transition to a low-carbon economy. One way to produce sustainable hydrogen is through the dry reforming of biogas, a gas generated by the decomposition of organic matter and composed mainly of methane (CH_4) and carbon dioxide (CO_2). Dry reforming of biogas not only helps reduce greenhouse gas emissions but also contributes to the sustainable production of hydrogen and syngas, a gas mixture (H_2 + CO) that is industrially significant to produce hydrocarbons, dimethyl ether, and others. The most used catalysts for the sustainable production of hydrogen through biogas reforming are based on nickel supported on alumina. However, the addition of promoters is necessary to maximize hydrogen production since Ni/Al_2O_3 catalysts suffer rapid deactivation due to high coke deposition. The incorporation of lanthanum, magnesium, and cerium oxides into NiO-Al_2O_3 catalysts is essential to improve thermal stability, reduce coke formation, and increase catalytic activity. Lanthanum oxide (La_2O_3) enhances thermal stability, magnesium oxide (MgO) prevents coke deposition, and cerium oxide (CeO_2) improves nickel particle dispersion and aids in carbon removal. This combination results in more efficient and durable catalysts, which are crucial for sustainable hydrogen production via biogas reforming. The present work aims to evaluate NiO-MxOy-Al_2O_3 catalysts (M = Mg, Ce, and La) prepared by the combustion method under dry reforming conditions for sustainable hydrogen production. Additionally, it aims to produce catalysts with low coke deposition, as coke formation is one of the major issues with conventional NiO-Al_2O_3 catalysts. The XRD shows that all catalyst present NiO and $NiAl_2O_4$ spinel phase and exhibited type IV(a) N_2 adsorption/desorption isotherms, characteristic of mesoporous materials. TPR-H_2 profiles presents reduction peaks associated to NiO and $NiAl_2O_4$ phases. The catalysts showed CH_4 and CO_2 conversion values ranging from 59.4-70.1% and 80.4-89.2%, respectively, and H_2 yield values varying between 38.6-42.7%. Coke deposition on the catalysts was low, ranging from 2.68-6.04%, with the cerium-containing catalyst showing the best CH_4 and CO_2 conversion results and, consequently, the highest H_2 yield. This is attributed to cerium promoting greater dispersion of NiO within the catalysts, thereby enhancing catalytic performance. The catalysts were stable during six hours of reaction, maintaining catalytic activity throughout the period, indicating their potential for longer-term applications.

Keywords: Dry reforming, Biogas, Sustainable Hydrogen, Syngas.

References

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