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Comparison of the efficiency of Ni/CaO and Ni/CaO@SiO_2 catalysts for CO_2 capture and syngas production through CH_4 reforming

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Keywords: CO_2 capture, dry reforming of CH_4, multifunctional catalysts, nanoparticles, mesoporous silica.

Highlights

Aiming high-temperature stability and sintering mitigation in catalytic conversion, the Ni/CaO@SiO_2 catalyst was prepared for CO_2 capture and conversion into syngas through CH_4 reforming.

Abstract

Climate change caused by CO_2 emissions has driven interest in sustainable and cost-effective techniques, such as carbon capture, storage, and utilization. Approaches based on isothermal catalytic transformation have emerged as promising alternatives by eliminating the costs associated with CO_2 storage and transportation. This study aimed to analyze methods that integrate adsorption and catalytic conversion, emphasizing using Ni/CaO-based catalysts coated with mesoporous SiO_2 for isothermal CO_2 capture and dry reforming of CH_4 to produce syngas.[1, 2]

The catalysts were prepared via the hydrothermal method using metal nitrates as precursors, ensuring control and homogeneity in particle size. A silicon alkoxide in an alkaline medium was used to promote the hydrolysis and coating of SiO_2, where a surfactant was employed to ensure the mesoporosity of the coating layer. The final solid was filtered, washed, and calcined in a muffle furnace at 650 ºC for 6 hours in an air atmosphere. Additionally, a reference uncoated Ni/CaO catalyst was synthesized to assess the impact of the SiO_2 coating.[3] The catalysts were characterized by thermogravimetric, temperature-programmed reduction (TPR) and N_2 physisorption analyses. For the Ni/CaO catalyst, it is possible to observe an intense mass loss (Figure 1a), indicating the loss of volatile materials, as well as a continuity as the temperature increases. This corroborates the choice of a calcination temperature of 600°C. For the Ni/CaO@SiO_2 catalyst, it can be seen that the material shows a gradual loss of mass between 100 °C and 250 °C due to the loss of moisture and volatile materials. After 600 °C, the mass loss becomes less pronounced, indicating that total decomposition has taken place; this final temperature was taken as the sample's calcination temperature. During the TPR of the Ni/CaO sample, intense H_2 consumption can be seen at 480°C (Figure 1b), indicating the reduction of nickel dispersed in the sample. For the Ni/CaO@SiO_2 sample, it is possible to identify a peak at 725°C, indicating the presence of nickel species interacting strongly with SiO_2, showing the encapsulation of the Ni and CaO nanoparticles, making it difficult to reduce them. The BET surface area of the Ni/CaO sample was 22 m²/g. Furthermore, N_2 physisorption analysis will be carried out on the Ni/CaO@SiO_2 catalyst to identify the increase in surface area, pore volume and size distribution. The CO_2 capture and catalytic tests will be carried out in a fixed-bed reactor with a MS gas analyzer to evaluate the efficiency of the catalysts. Further characterization and in-situ studies will allow the reaction mechanisms to be investigated.

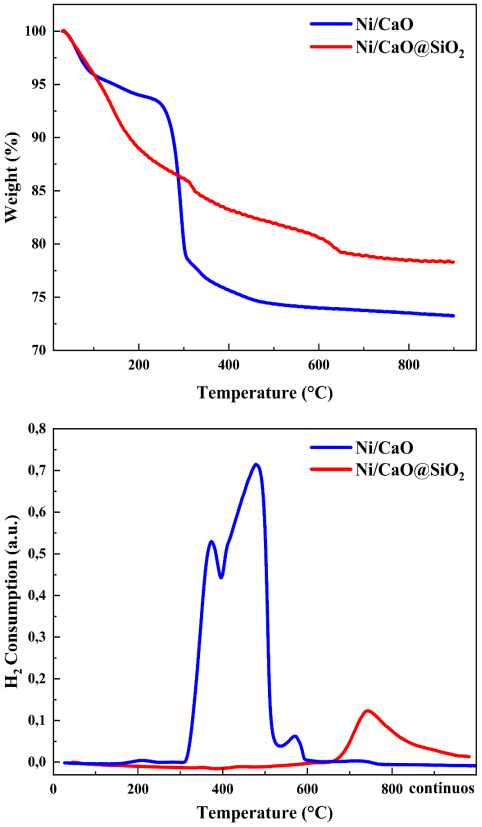

Figure 1. TGA (a) and TPR-H_2 (b) of Ni/CaO (blue) and Ni/CaO@SiO_2 (red)

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