Advanced silica-based nanostructured materials for simultaneous methanation of carbon oxides

A. Malara[1], C. Nunnari[1], L. Madeo[2], P. De Luca[3], A. Fotia[4], P. Frontera[1], A. Macario[2]

[1]Department of Civil, Energy, Environmental and Material Engineering, University Mediterranean of Reggio Calabria, Italy

[2]Department of Environmental Engineering, University of Calabria, Rende (CS), 87036, Italy

[3]Department of Mechanical, Energy and Management Engineering, University of Calabria, Rende (CS), 87036, Italy

[4]CNR Institute for Advanced Energy Technologies (ITAE), 98126, Messina, Italy

E-mail: macario@unical.it

Nanotechnologies have facilitated the development of compact, high-specific surface area, high-performance devices across various fields in recent decades. Among the methods for material fabrication, electrospinning stands out as particularly promising for producing fibrous nanostructures, thanks to its simplicity, cost-effectiveness, and capability for industrial-scale application. Its advantages include reliable reproducibility, adaptability, and precise control over fiber size. Additionally, catalysts play a crucial role in many processes, including decarbonization technologies aimed at combating global warming. In this research, catalytic systems utilizing nickel catalysts supported on silica-based micromaterials have been developed for the simultaneous methanation of carbon oxides. The synthesized microporous silica-based materials utilized an MFI structure, created from a gel precursor that included tetrapropyl ammonium hydroxide, water, ethanol, and a silica source. Metal loading onto the support was achieved through impregnation of the nanofiber/support produced via electrospinning. Various techniques such as XRD, SEM-EDX, HR-TEM, N_2 Adsorption/Desorption, Fourier Transform Infrared Spectroscopy (FTIR), and TG-DSC were employed to examine phase identification, morphology, crystal dimensions, structural properties, and thermal stability of the fresh catalyst. The Ni/MFI powder, characterized by its rounded particle morphology, served as a benchmark for assessing catalytic performance under identical experimental conditions. The conversion of CO_2 and the production of CH_4 remained stable across all samples over a continuous 15-hour period without any alterations. The catalytic performance of the electrospun sample Ni/f-MFI, evaluated in terms of CH_4 production and CO_2 conversion, highlighted the impact of the nanofiber structure on catalytic efficiency. The catalysts supported on nanofibers demonstrated improved CO_2 conversion and CH_4 production when compared to the powdered reference sample. Scanning electron micrographs of the used catalysts revealed that the fiber morphology was maintained as a compact yet brittle mat, even though the catalysts experienced some reduction in elasticity and flexibility due to sustained activity under high temperatures. These findings are particularly significant for preventing catalyst leakage, which is crucial for straightforward recovery, especially in plug-flow reactors, where enhancing operational stability remains a challenge.

***Keywords**: methane, carbon oxides, silica-based materials, nanofibers, electrospinning, decarbonization.*