Supplementary Information

Effect of ceria promotion on the catalytic performance of Ni/SBA-16 catalysts for CO$_2$ methanation

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The CO$_2$ methanation activity of 10Ni/10Ce/SBA-16 at different reduction condition
Fig. S1. The CO$_2$ methanation test of 10Ni/10Ce/SBA-16 catalyst reduced at different temperatures; a) CO$_2$ conversion (%), b) CH$_4$ selectivity (%)

As shown in Fig. S1, the 10Ni/10Ce/SBA-16 catalyst reduced at 500 °C showed better CO$_2$ conversion and CH$_4$ selectivity compared to that reduced at 800 °C. This could be assigned to the shrinkage of support at high temperature, resulting in less accessible sites of Ni and Ce.

*The CO$_2$ methanation activity of 10Ni/5Ce/SBA-16 at different reduction condition*
As shown in Fig. S2c, the 5 wt.% Ce modified Ni/SBA-16 catalyst shows a worse activity compared to other catalysts at the testing temperature range. In Fig. S2 a and b, it also can be seen that the activity and CH₄ selectivity decrease as the increase of reduction temperature until 900 °C. Thus, it can be concluded that 10 wt.% Ce is an appropriate
content for Ce-promoted Ni/SBA-16 catalyst in CO\(_2\) methanation and 500 °C is the best condition for reduction process.

**The low-angle XRD of the synthesized SBA-16 support**

As shown in Fig. S3, two small peaks at \(\theta=1.25\) and 1.56 were observed for SBA-16 support, representing (200) and (211) reflection, respectively, indicating the existence of ordered mesopores in SBA-16 with body-centered cubic symmetry (\(Im\bar{3}m\)).

![Fig. S3. Low-angle XRD of the synthesized SBA-16 material](image)
The supplementary TEM images of reduced catalysts

Fig. S4. TEM micrographs of the reduced catalysts; Condition: 500 °C for 1 h (H₂/Ar=5/95, 100 mL/min); a, b) 10Ni/SBA-16, c) 10Ni/10Ce/SBA-16, d) 10Ni/20Ce/SBA-16

The supplementary TEM images were displayed in Fig. S4. As shown in Fig. S4, indeed these images presented a cubic array of uniform channels when the incident electron beam was parallel to the main axis of the mesopores (a, c, d) and also unidirectional or hexagonal channels when the electron beam took different orientations with respect to the sample (b), which demonstrates that the order structure of SBA-16 was preserved despite the incorporation of Ce and Ni into the pores.

Characterization of the catalysts after CO₂ methanation test
The XRD of the catalysts after test were also performed and the patterns were displayed in Fig. S5. As show in Fig. S5, the spent catalysts showed similar Ni and CeO$_2$ crystallites like reduced catalysts (Fig.2b). The broad peaks of Ni species indicate that no sintering of Ni active metal happened during reaction. The structure of CeO$_2$ also remains stable for Ce-doped catalysts.

References