

Supplementary data

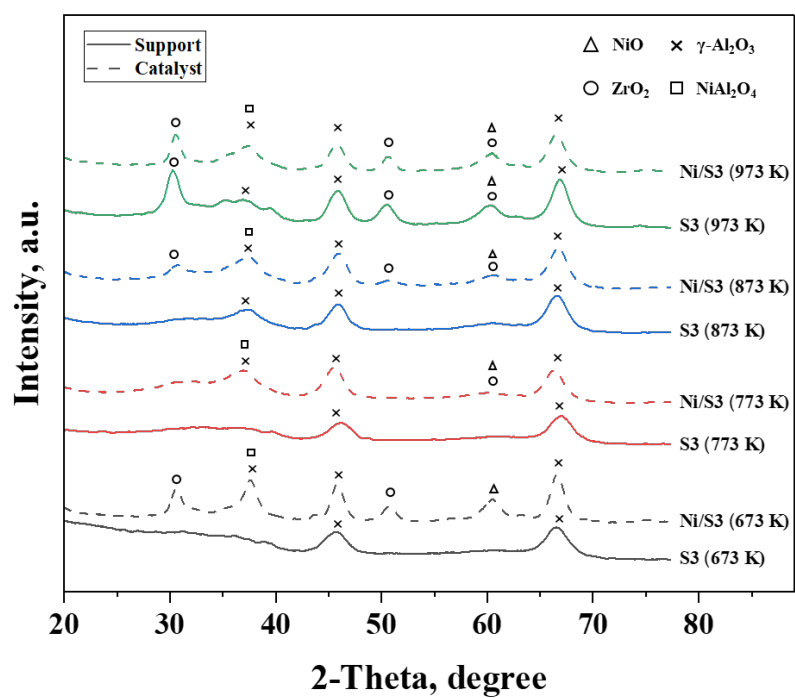


Figure S1. XRD patterns of S3 and Ni/S3 with various calcined temperatures.

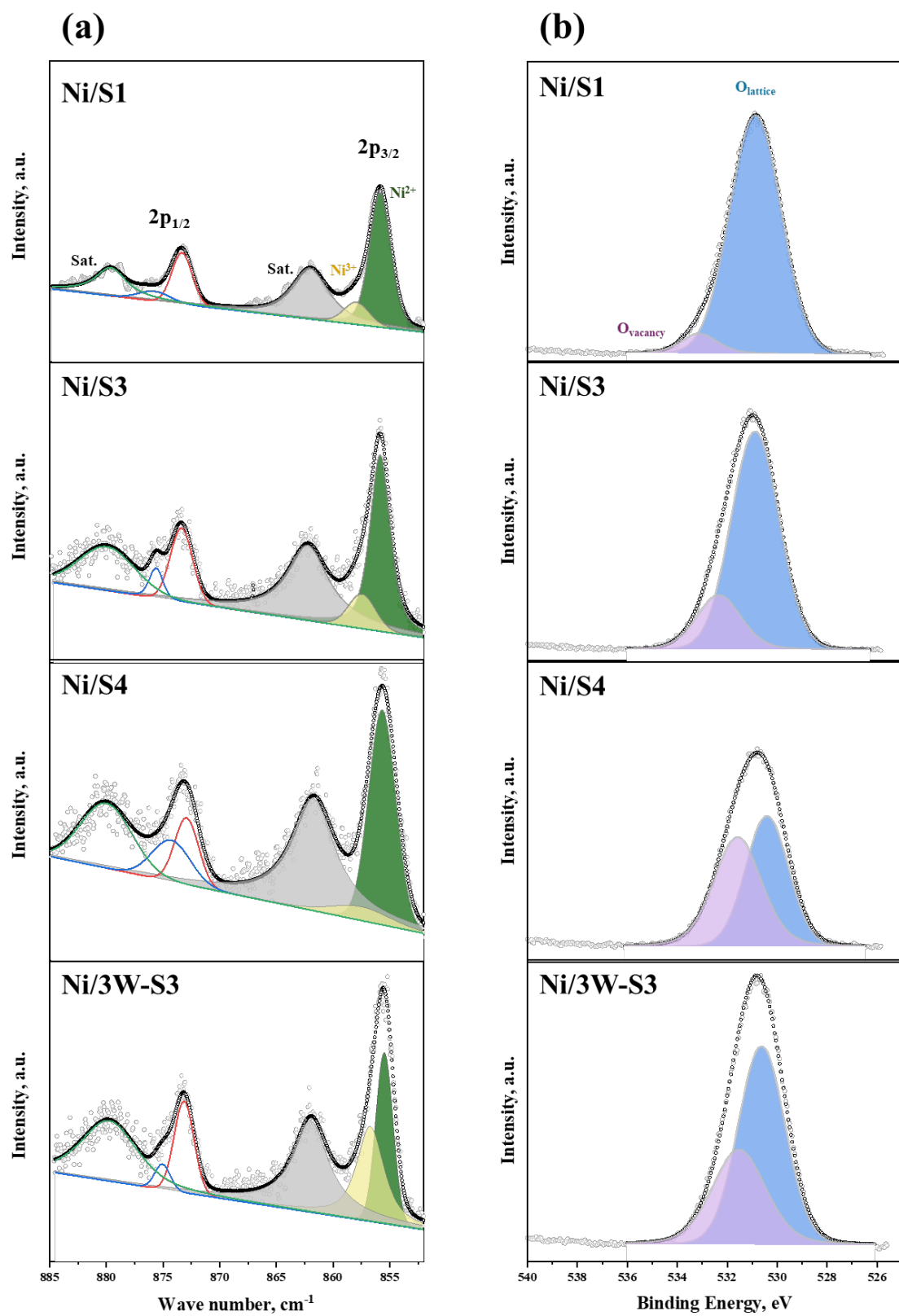


Figure S2. Ni 2p(a) and O 1s(b) XPS spectra of the catalysts.

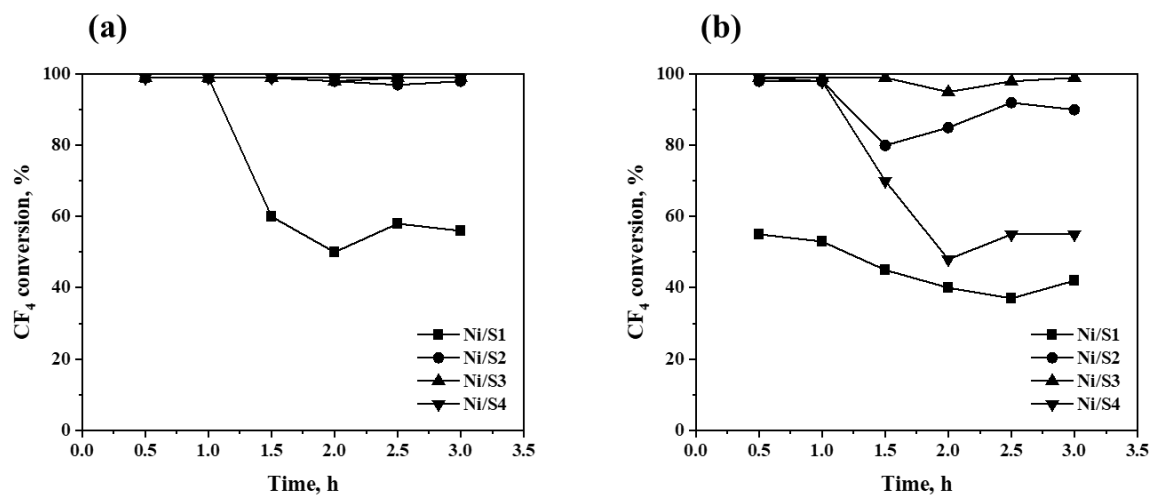


Figure S3. CF₄ conversion over time for catalysts prepared with various ZrO₂ contents (a) 973 K and (b) 923 K.
(SV: 4,000 h⁻¹, 300 cc/min flow, CF₄: 1000ppm, H₂O: 8 v/v%)

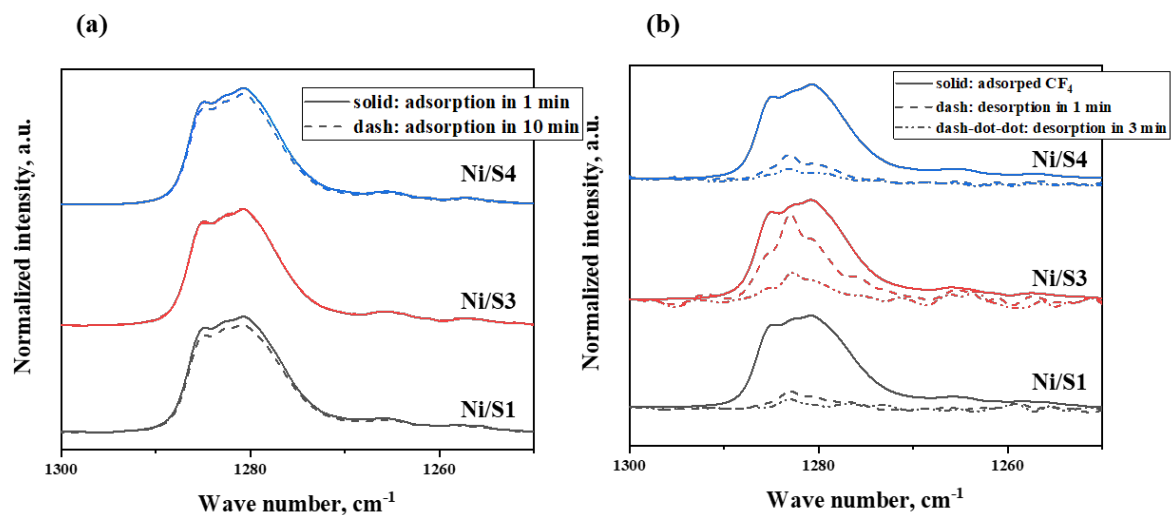


Figure S4. FT-IR spectra of (a) CF_4 adsorbed and (b) desorbed on catalysts as various ZrO_2 contents.

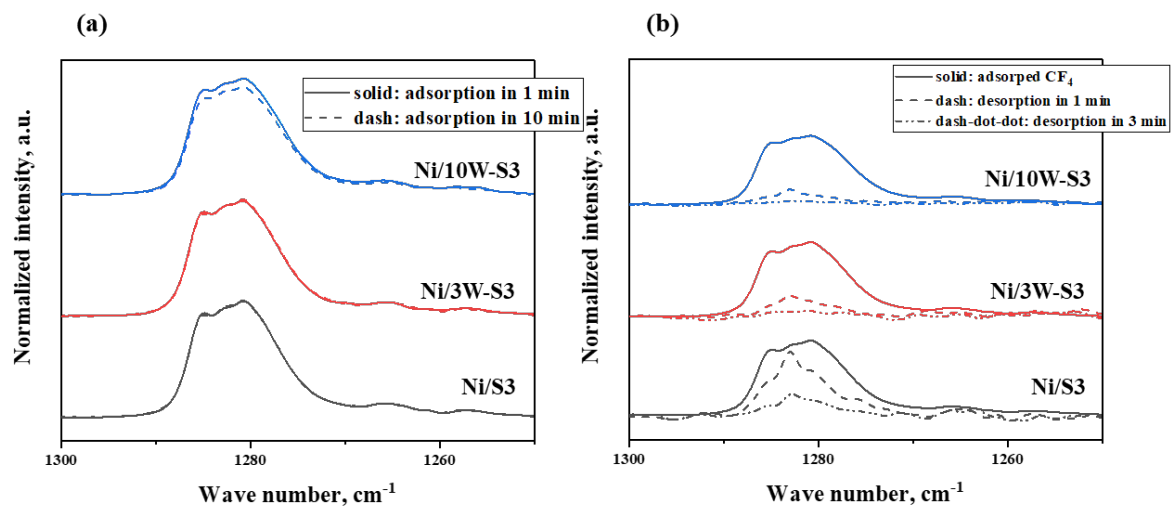


Figure S5. FT-IR spectra of (a) CF_4 adsorbed and (b) desorbed on catalysts based on tungsten addition amounts. Solid line