Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary information

Unveiling remarkable enhancement role by designing the confined structure Ho-TNTs@Mn catalyst for low-temperature NH_3-SCR reaction

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Materials characterization

A transmission electron microscope (TEM: JEOL JEM-6701F) equipped with an energy dispersive X-ray spectrometer, the morphology of all materials was investigated. The crystal information on the surface of the catalyst was examined using a Rigaku D/MAX-Rb X-ray diffractometer that offered a scanning angle range of 10-80°. Raman spectra were measured in 100-1000 cm^{-1} using a LabRam HR Evolution Raman microscope. Measurements of all samples were measured under a diode-pumped solid-state laser with an excitation wavelength of 532 nm. The catalyst void parameters such as BET specific surface area, pore volume, and average pore size were tested using a Micrometrics ASAP 2020 specific surface area and pore size analyzer. The adsorption of nitrogen was carried out at 76.2 K. The valence distribution and elemental concentration of the elements on the catalyst surface were determined using a VGESCALAB 210 X-ray photoelectron spectrometer. C 1s (B. E= 284.8 eV) was used to calibrate the collected data. A TP-5080-D multifunctional dynamic adsorber was utilized to examine H_2-TPR and NH_3-TPD. A 0.05 g sample was prepped with high purity nitrogen for 1h at 30 °C before being evaluated in an environment containing 5 vol% H_2 and 95 vol% N_2 at a ramp rate of 10 °C/min in 30-900 °C. At a ramp rate of 10°C/min in 100-800 °C, the gas flow rate of NH_3-TPD was kept under control at 30 mL/min. TG/DTA measurements were made on a NETZSCH STA 449F3 instrument heated from 23 °C to 800 °C in the air at 10 °C/min.

Chart list

TNTs@Mn(c).

Table S1．Peak area of different acidic sites in each catalyst in NH_3-TPD.

Table S2. ICP Results of Ho-TNTs@Mn.

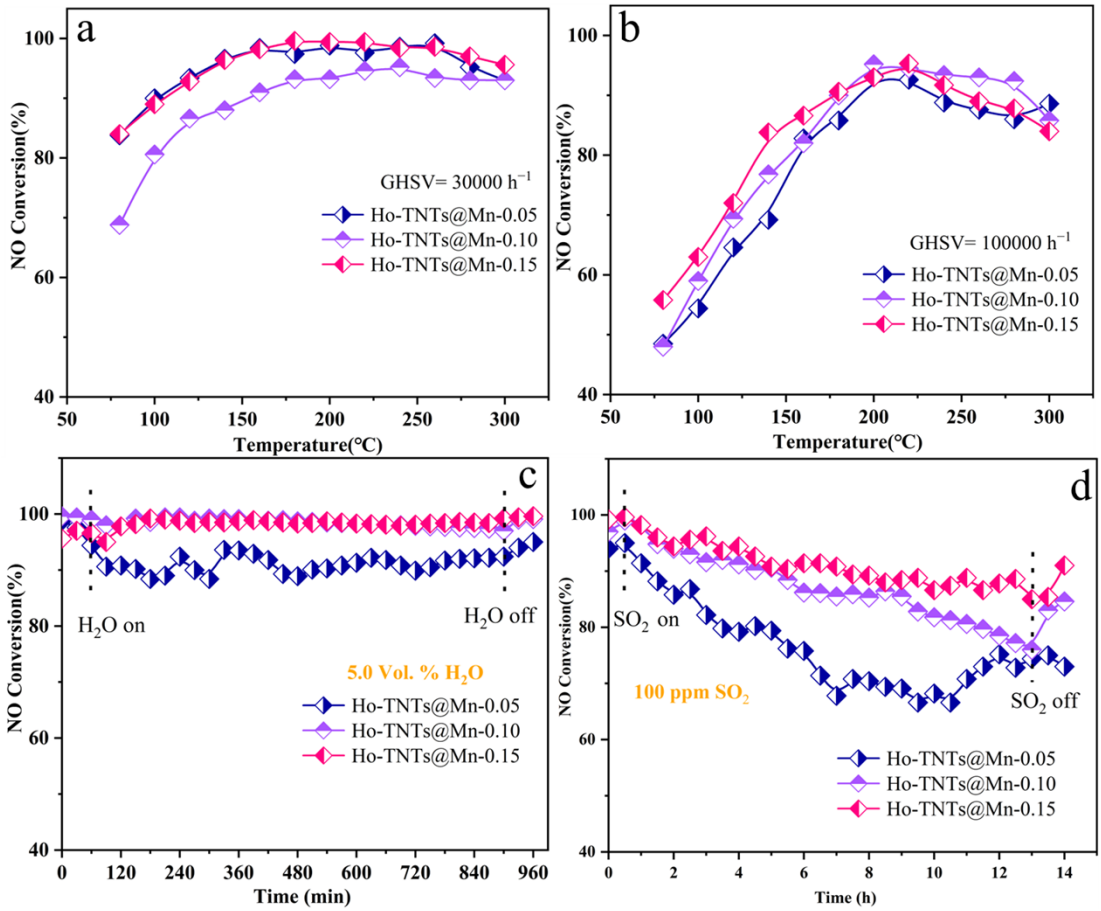

Figure S1. (a-b) NH_3-SCR activity of Ho-TNTs@Mn-x catalyst at GHSV= 30000 h^{-1} (a) and GHSV= 100000 h^{-1} (b). (c) NO conversion of Ho-TNTs@Mn-x in the presence of H_2O at 180 °C. (d) the effect of SO_2 on NO conversion over Ho-TNTs@Mn-x at 180 °C.

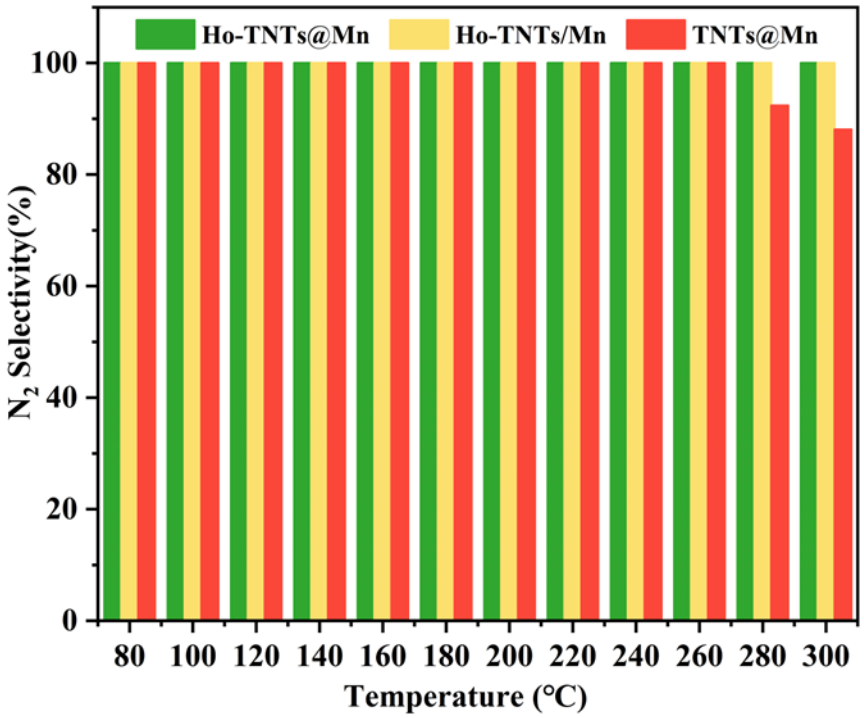

Figure S2. N_2 selectivity of catalysts Ho-TNTs@Mn, Ho-TNTs/Mn and TNTs@Mn catalyst.

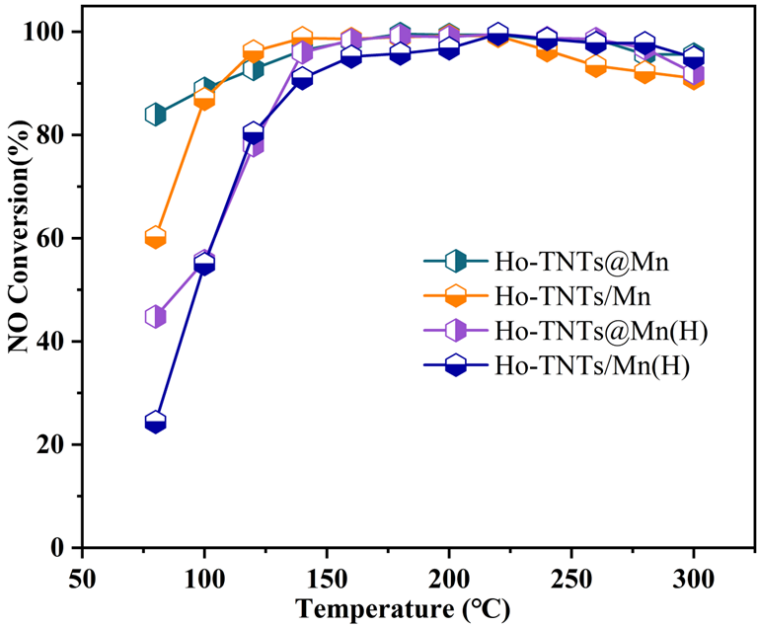

Figure S3. Comparison of before and after passing water (5 vol% H_2O) of SCR activity over Ho-TNTs@Mn and Ho-TNTs/Mn in the range of 80-300 °C.

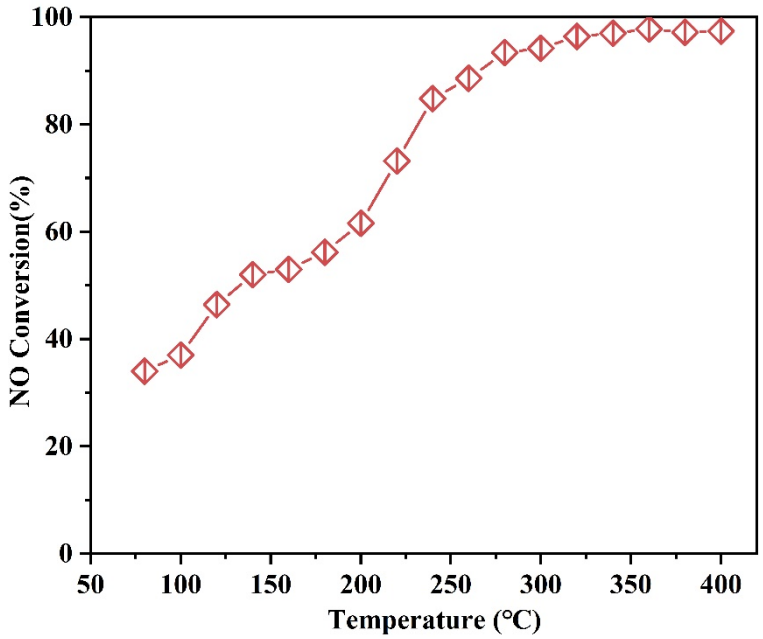

Figure S4. NH_3-SCR activity of regenerated Ho-TNTs@Mn catalyst (regarded as Ho-TNTs@Mn(R)) with 350 °C.

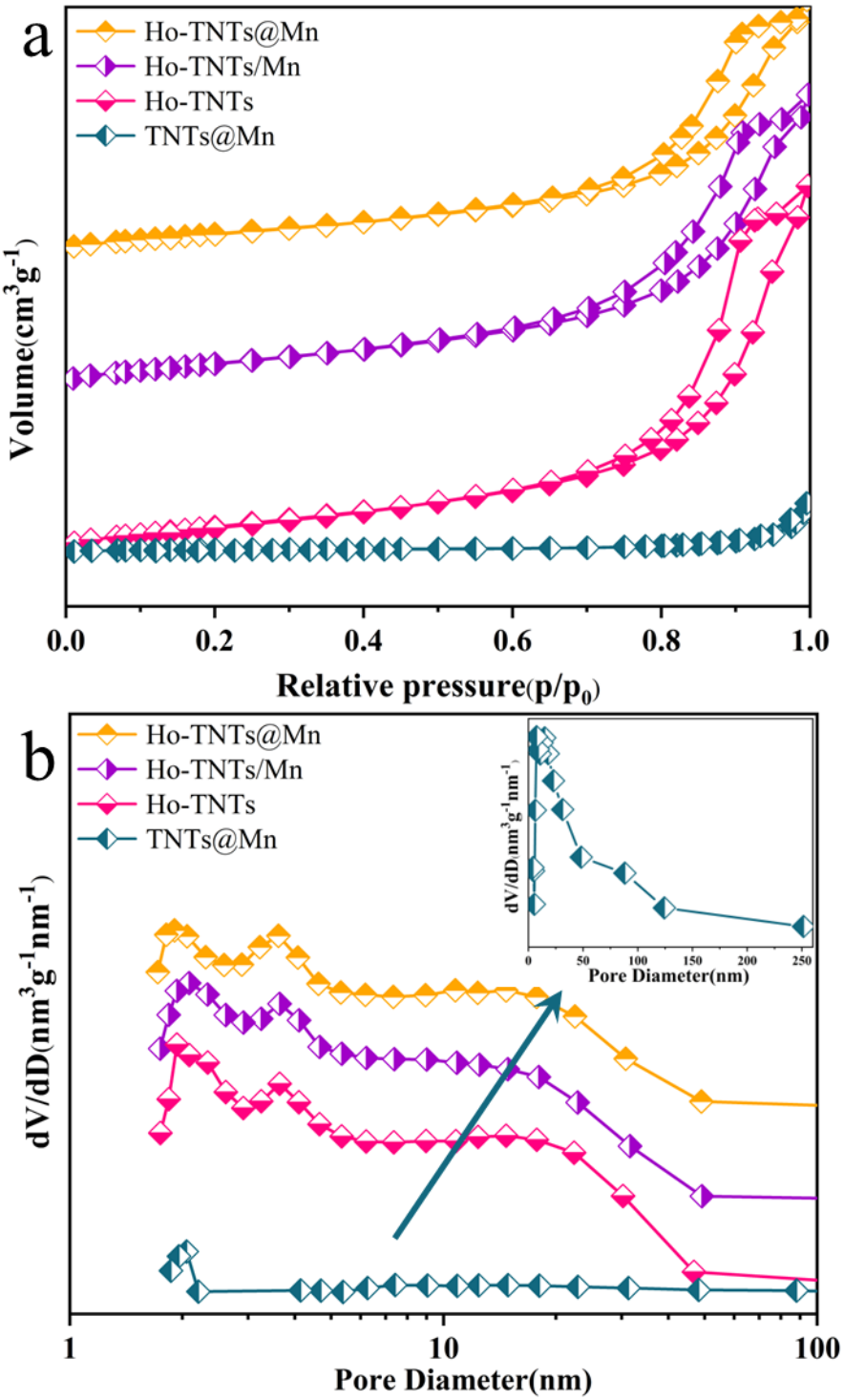

Figure S5. N_2 ad-desorption isotherms (a) and BJH desorption pore distribution (b) of Ho-TNTs/Mn, Ho-TNTs@Mn, TNT@Mn, and Ho-TNTs.

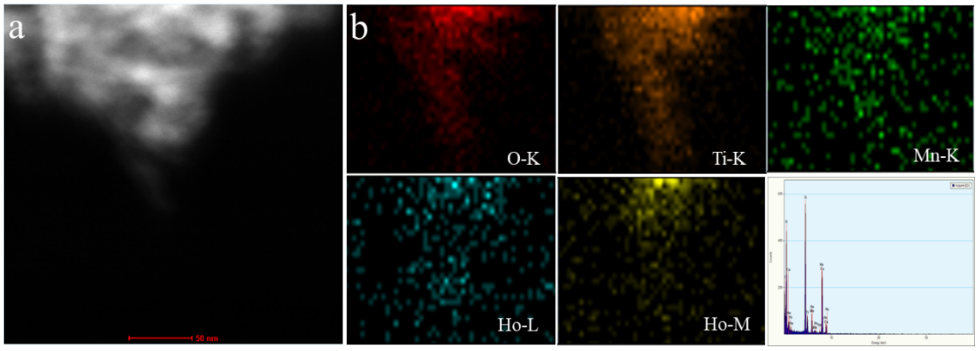

Figure S6. TEM-EDX mapping of Ho-TNTs@Mn.

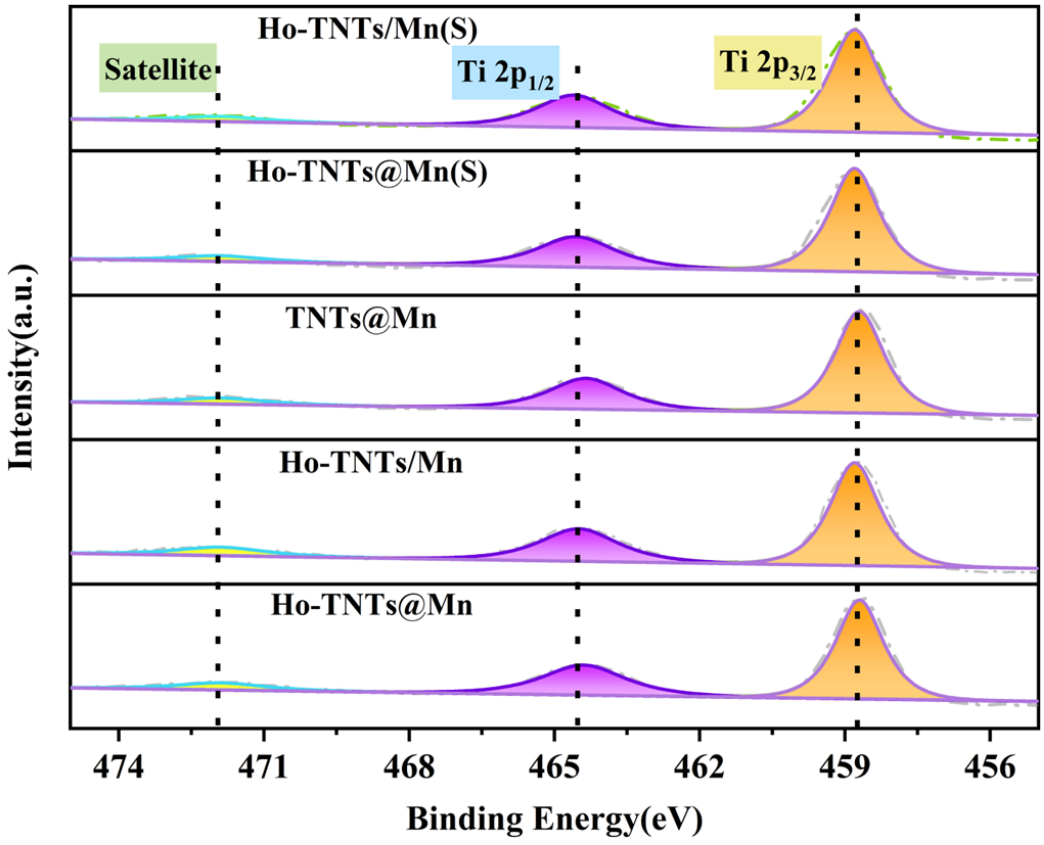

Figure S7. XPS spectra of Ti 2p of Ho-TNTs/Mn, Ho-TNTs@Mn, TNT@Mn, Ho-TNTs@Mn(S) and Ho-TNTs/Mn(S).

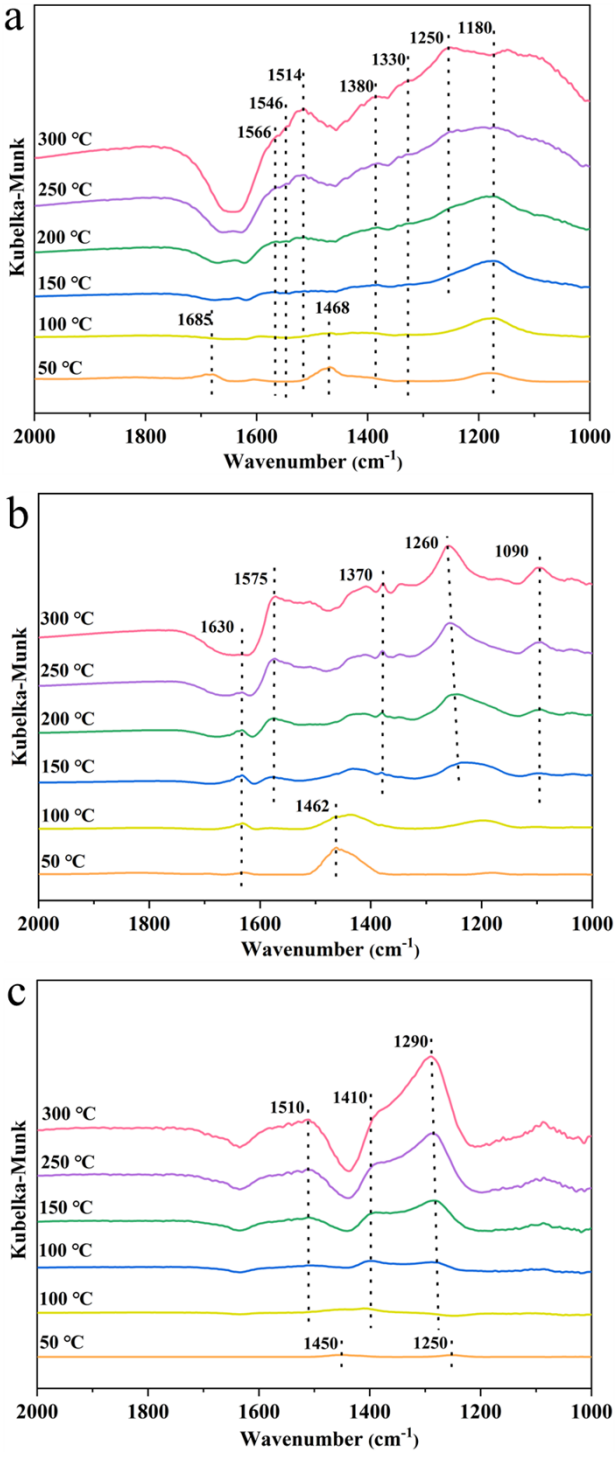

Figure S8. In situ DRIFTs of NH_3 desorption exposed to N_2 flow with temperature over the catalyst Ho-TNTs@Mn (a), Ho-TNTs/Mn(b), and TNTs@Mn(c).

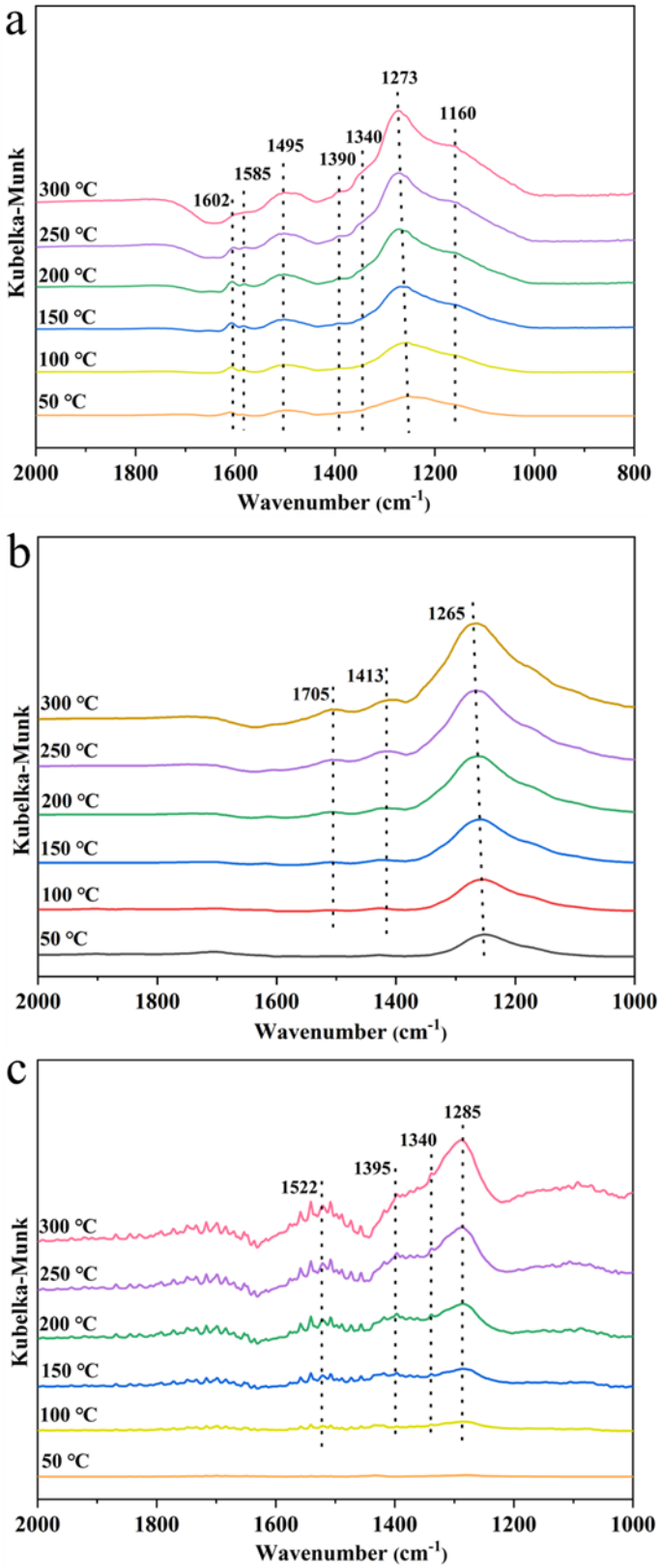

Figure S9. In situ DRIFTs spectra of SO_2 + NO + O_2 desorption over Ho-TNTs@Mn (a), Ho-TNTs/Mn(b), and TNTs@Mn(c) catalyst as a function of temperature.

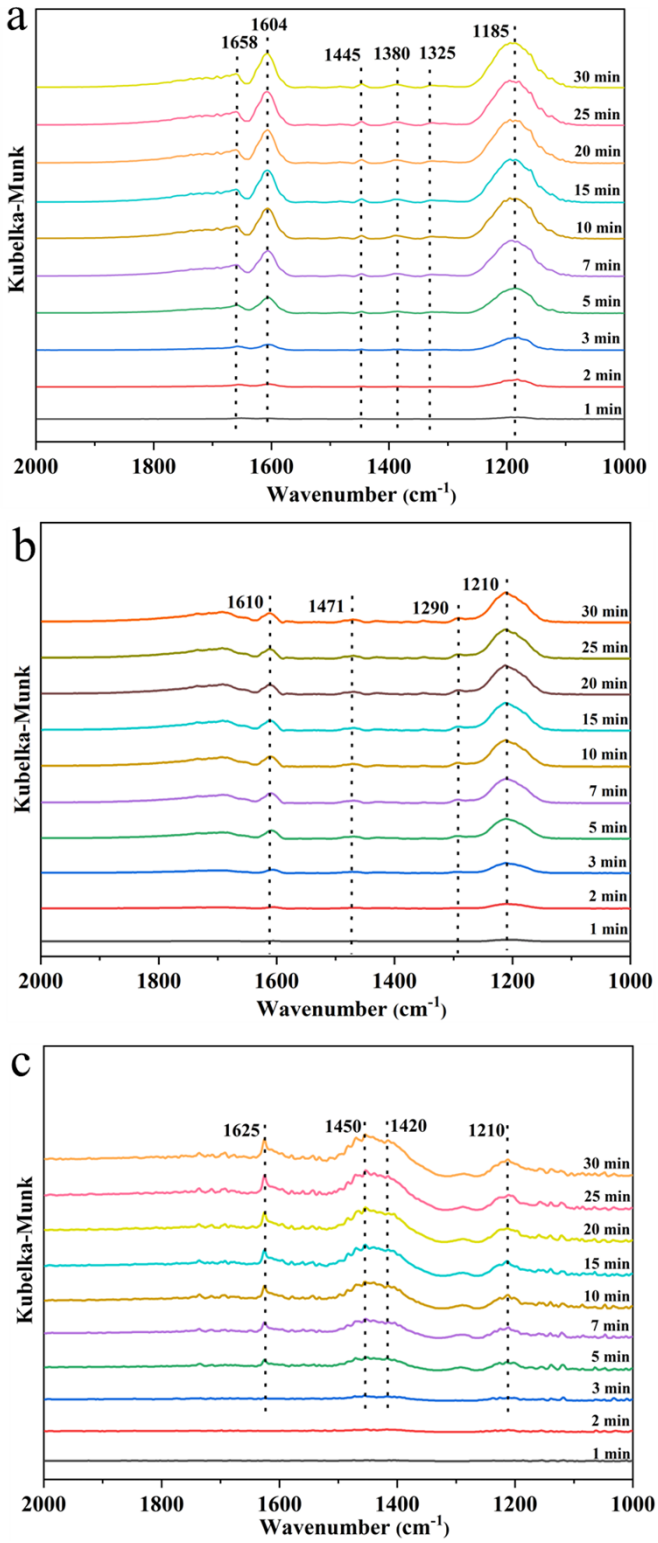

Figure S10. In situ DRIFTs spectra of NH_3 adsorption at 200 °C with time over Ho-TNTs@Mn (a), Ho-TNTs/Mn(b), and TNTs@Mn(c).

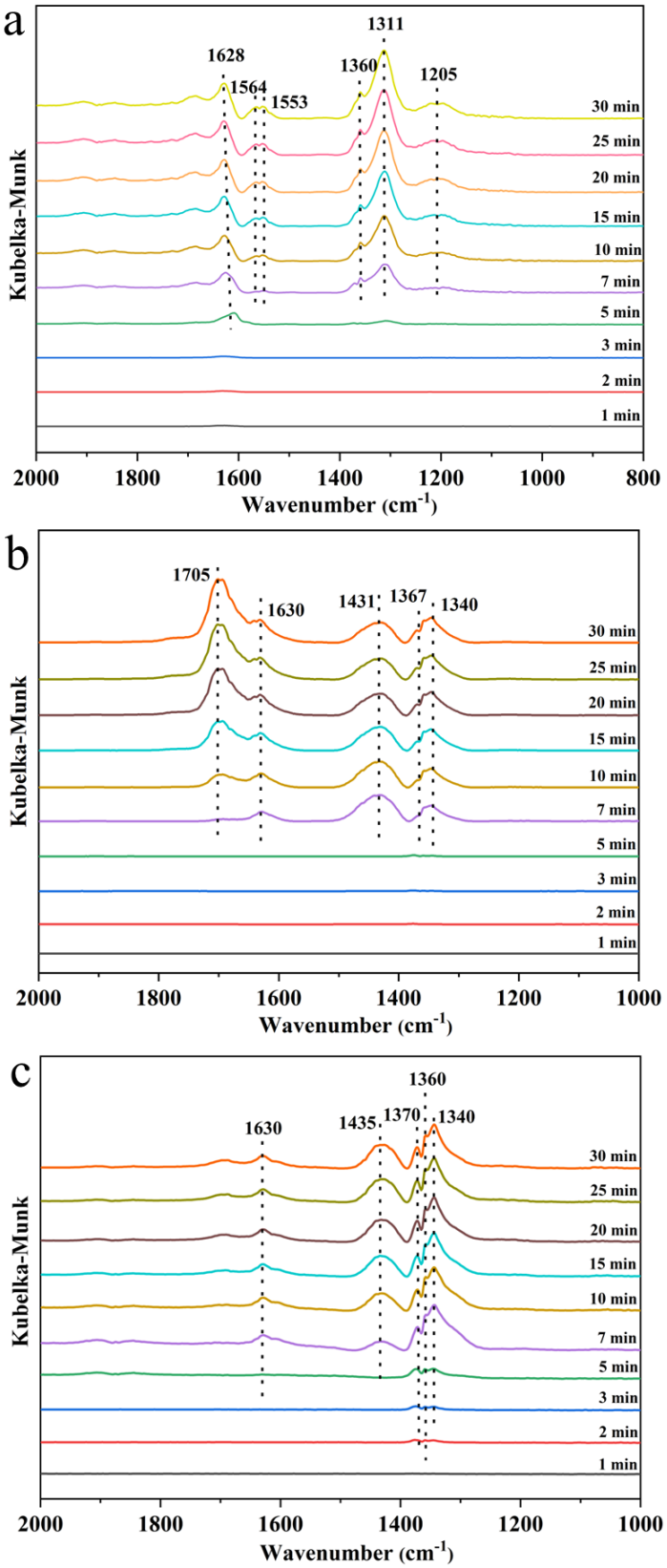

Figure S11. In situ DRIFTs spectra of SO_2 + NO + O_2 adsorption at 200 °C with time over Ho-TNTs@Mn (a), Ho-TNTs/Mn(b), and TNTs@Mn(c).

Table S1. Peak area of different acidic sites in each catalyst in NH_3-TPD.

Samples	Weak acid sites (a.u.)	Med-strong acid sites (a.u.)	Strong acid sites (a.u.)	Total areas (a.u.)
Ho-TNTs@Mn	487.2	420.0	310.0	1217.2
Ho-TNTs/Mn	595.6	95.0	305.0	995.6
Ho-TNTs	741.9	57.0	0	798.9
TNTs@Mn	74.8	20.0	165.8	260.6

Table S2. ICP Results of Ho-TNTs@Mn.

Sample	Sample Quality (g)	Test Element	Test Data (mg/L)	Load Content (wt.%)
Ho-TNTs@Mn	0.0194	Ho	1.53	0.99
		Mn	3.67	2.36
		S	1.22	0.79