Supporting Information

Mesoporous Mn-Ti amorphous oxides: a robust low-temperature NH_3-SCR catalyst

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In order to comprehensively evaluate the activity of Mn-Ti amorphous oxide catalysts in this study, the MnO_x/TiO_2(im) and MnO_x-TiO_2(co) catalysts with the same ratio of $n_{Mn}/(n_{Ti}+n_{Mn})$ in $Mn_{0.5}Ti_{0.5}$ were prepared as comparisons by conventional impregnation and co-precipitation methods, respectively.

For impregnation method, manganese nitrate and P25 were used as the precursor and support, respectively. After impregnation, the excess water was removed in a rotary evaporator. The sample was dried at 60 ºC for 2 days and then calcined at 500 °C for 4 h to obtain MnO_x/TiO_2(im) catalyst.

For co-precipitation method, titanium sulphate and manganese nitrate were dissolved completely in 100 mL deionized water and stirred. Then ammonia water was gradually added until the pH value of mixed solution reached 10. The mixture was stirred at room temperature for 3 h and then aged for 1 h. The precipitation was filtered and washed with deionized water for five times. The sample was dried at 60 ºC for 2 days and then calcined at 500 °C for 4 h to obtain MnO_x-TiO_2(co) catalyst.

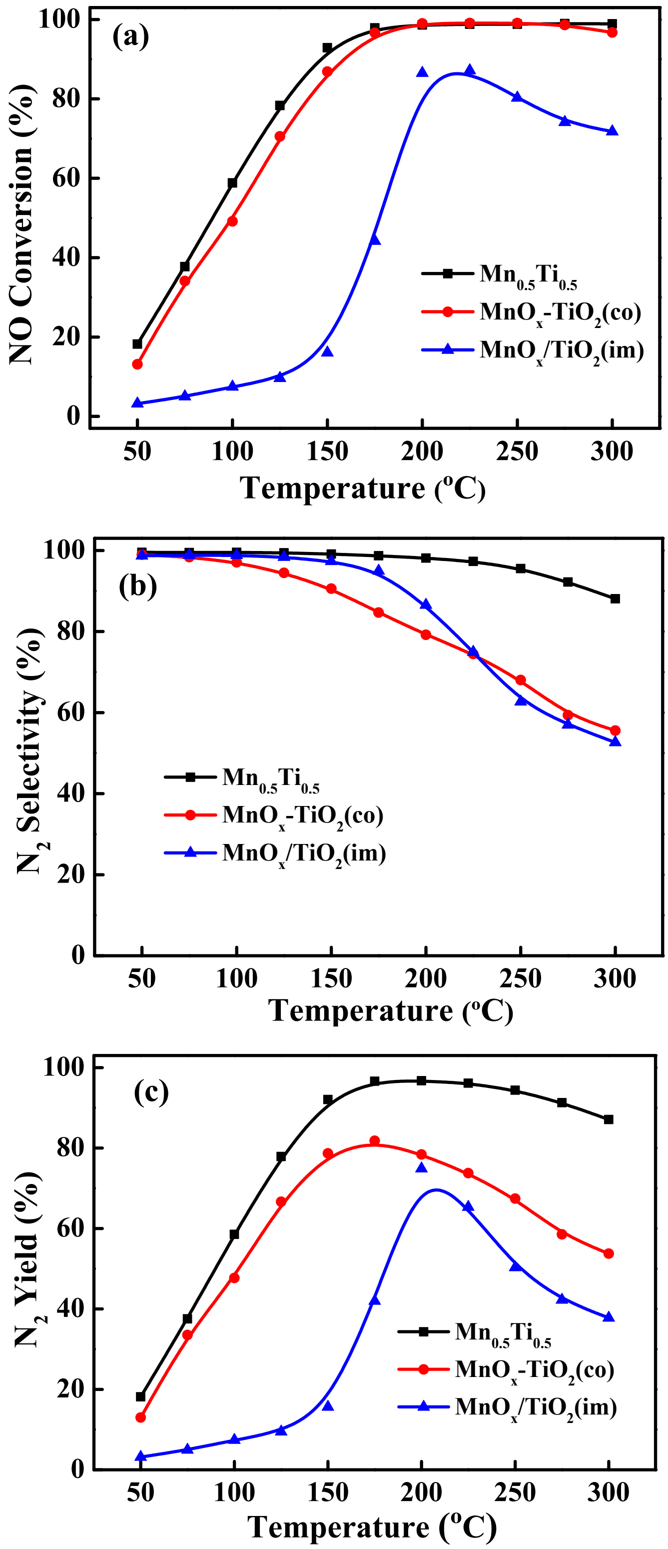


Fig. S1 NH_3-SCR performance of $Mn_{0.5}Ti_{0.5}$, MnO_x-TiO_2(co) and MnO_x/TiO_2(im) catalysts: (a) NO conversion; (b) N_2 selectivity; (c) N_2 yield. Reaction conditions: [NO] = [NH_3] =1000 ppm, [O_2] = 3 vol.% and N_2 as balance gas.

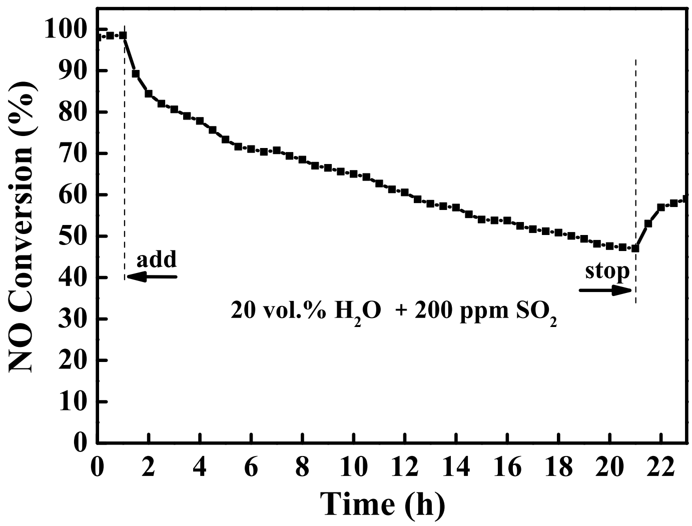


Fig. S2 H_2O + SO_2 durability tests of $Mn_{0.5}Ti_{0.5}$ catalyst at 200 °C. Reaction conditions: [NO] = [NH_3] = 1000 ppm, [SO_2] =200 ppm, [H_2O] = 20 vol.%, [O_2] = 3 vol.%, balance N_2.

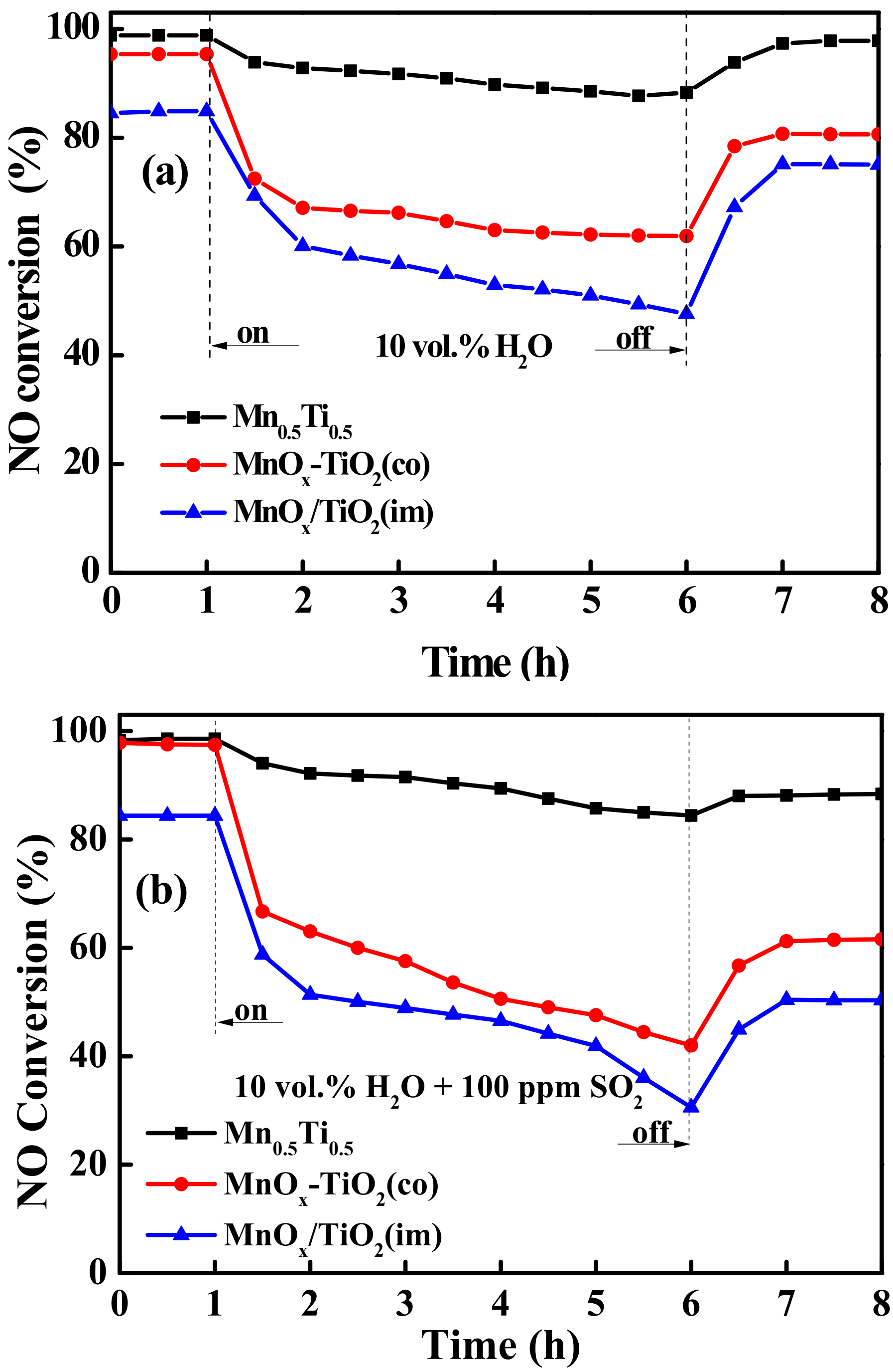


Fig. S3 (a) H_2O and (b) H_2O + SO_2 durability tests of $Mn_{0.5}Ti_{0.5}$, MnO_x-TiO_2(co) and MnO_x/TiO_2(im) catalysts at 200 °C. Reaction conditions: [NO] = [NH_3] = 1000 ppm, [SO_2] =100 ppm, [H_2O] = 10 vol.%, [O_2] = 3 vol.%, balance N_2.

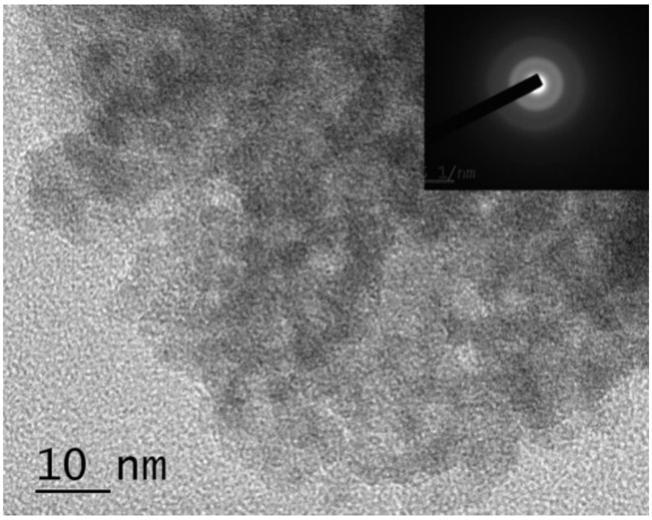


Fig. S4 HRTEM image and SAED pattern (inset) of the $Mn_{0.3}Ti_{0.7}$ catalyst.

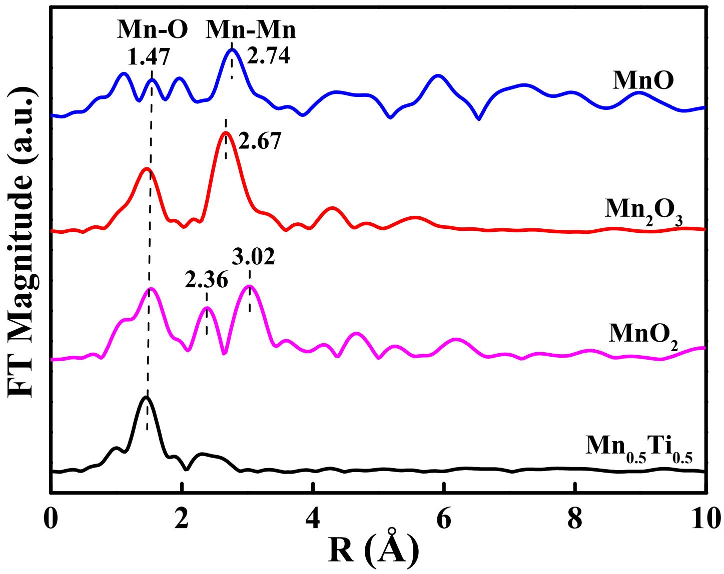


Fig. S5 Mn K-edge radial structure functions of reference compounds and $Mn_{0.5}Ti_{0.5}$ catalyst.

Fig. S5 presents the radial structure functions of Mn K-edge of the reference oxides (MnO, Mn_2O_3, and MnO_2) and the $Mn_{0.5}Ti_{0.5}$ catalyst. As shown in **Fig. S5**, All spectra of the samples showed the coordination peaks with different intensities at 1.47 Å, which could be ascribed to Mn-O band, while the peaks at 2-4 Å were attributed to Mn-Mn bonds.[1,2] Furthermore, the EXAFS spectrum for $Mn_{0.5}Ti_{0.5}$ catalyst was different from that of the reference oxide, indicating that the unique chemical states of manganese species in $Mn_{0.5}Ti_{0.5}$ catalyst caused by the strong interaction between Mn and Ti.

[1] Q. Tang, X. Huang, C. Wu, P. Zhao, Y. Chen and Y. Yang, ***J. Mol. Catal. A: Chem.***, 2009, 306,48-53.

[2] Q. Li, M. Meng, H. Xian, N. Tsubaki, X. Li, Y. Xie, T. Hu and J. Zhang, ***Environ. Sci. Technol***., 2010, 44, 4747-4752.

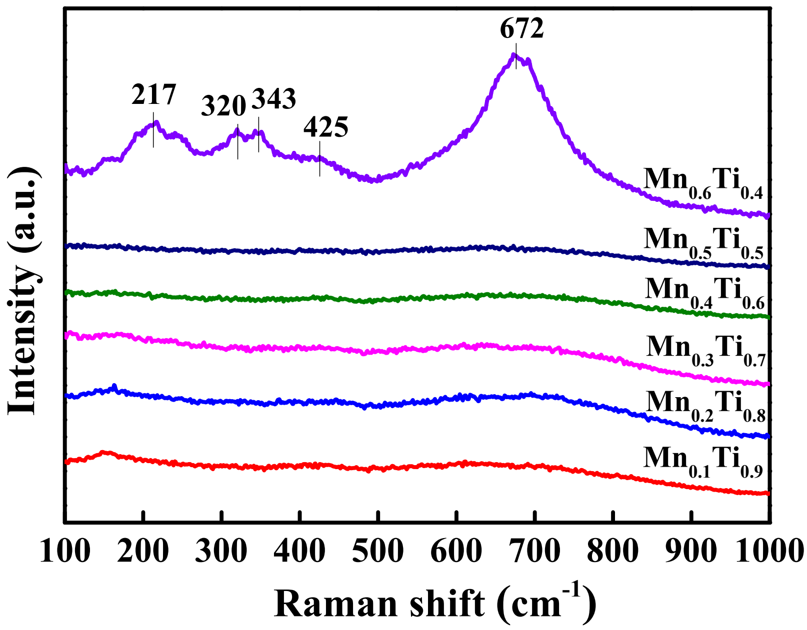


Fig. S6 Raman spectra of Mn_aTi_{1-a} catalysts.

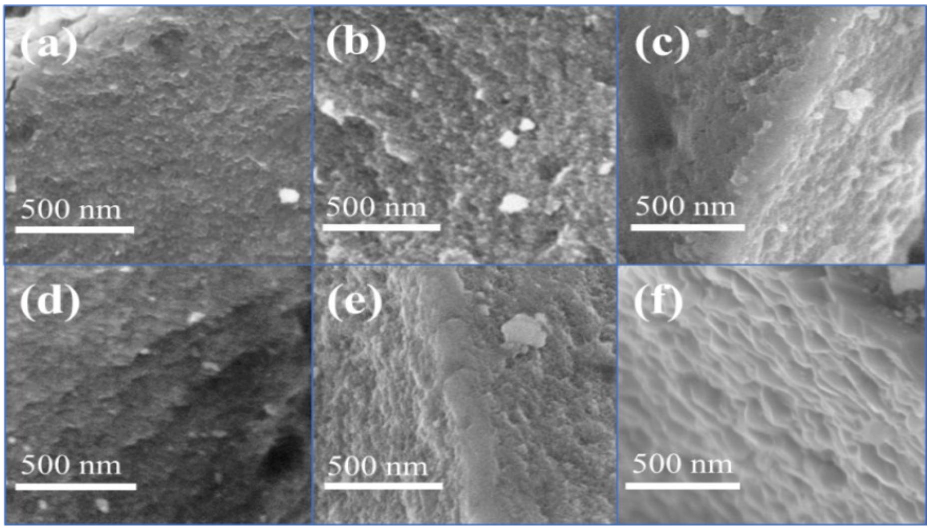


Fig. S7 SEM images of (a) $Mn_{0.1}Ti_{0.9}$, (b) $Mn_{0.2}Ti_{0.8}$, (c) $Mn_{0.3}Ti_{0.7}$, (d) $Mn_{0.4}Ti_{0.6}$, (e) $Mn_{0.5}Ti_{0.5}$ and (f) $Mn_{0.6}Ti_{0.4}$.

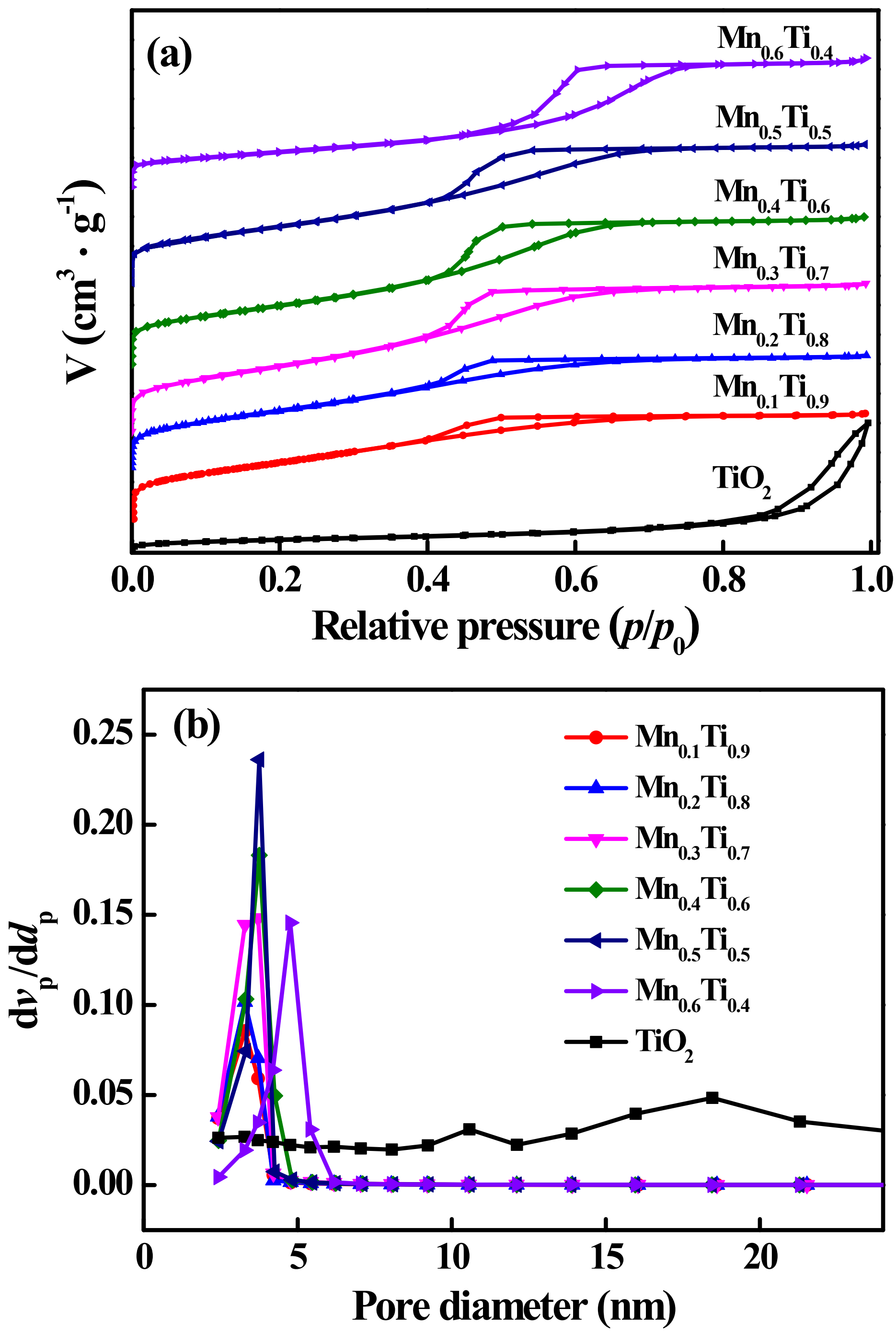
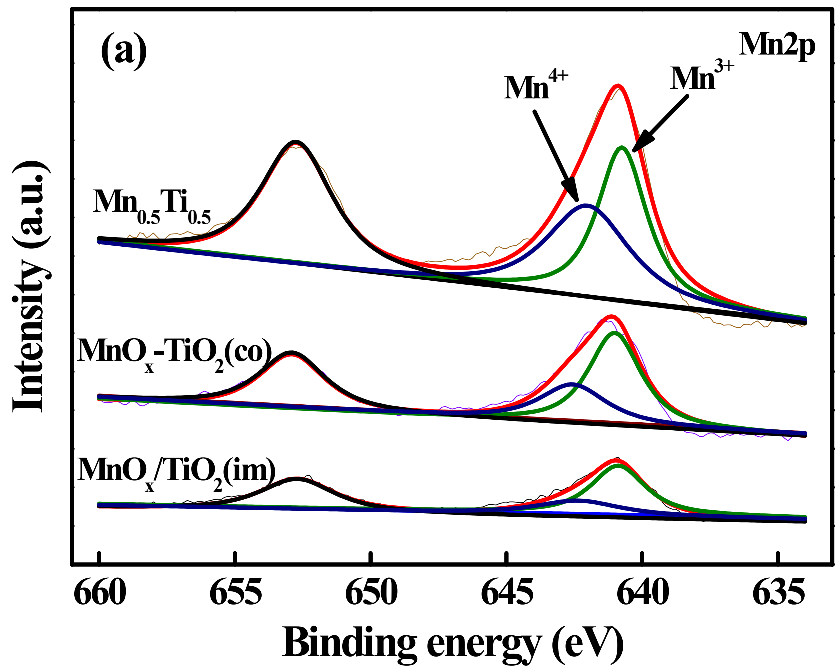


Fig. S8 (a) N_2 adsorption-desorption isotherms and (b) pore size distribution curves of the Mn_aTi_{1-a} and TiO_2 catalysts.



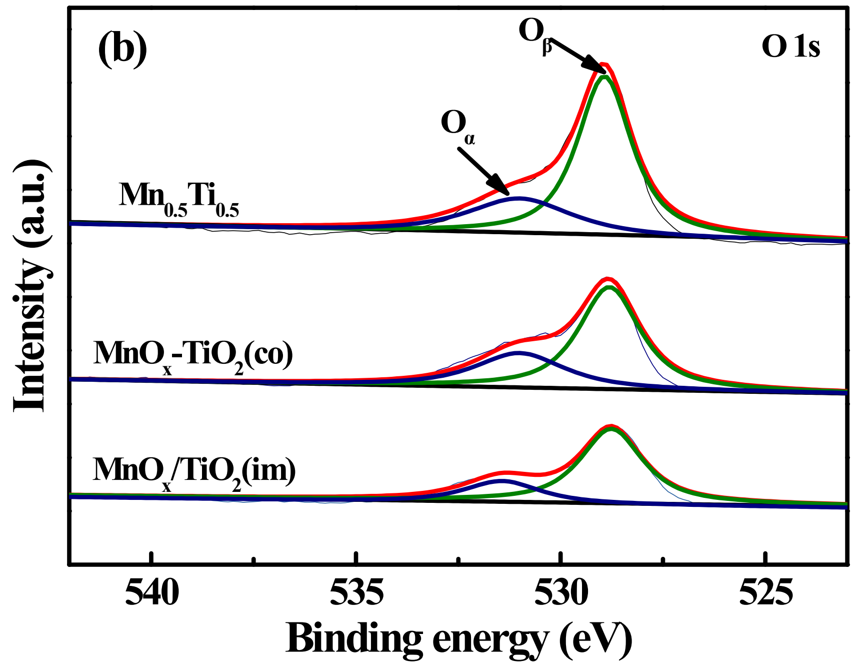


Fig. S9 (a) Mn 2p and (b) O 1s XPS spectra of $Mn_{0.5}Ti_{0.5}$, MnO_x-TiO_2(co) and MnO_x/TiO_2(im) catalysts.

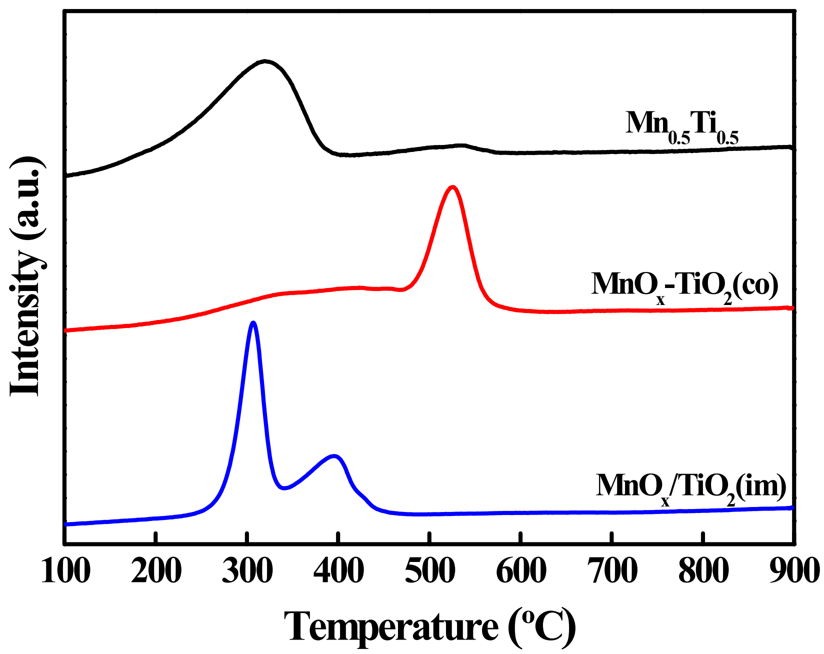


Fig. S10 H_2-TPR profiles of $Mn_{0.5}Ti_{0.5}$, MnO_x-TiO_2(co) and MnO_x/TiO_2(im) catalysts.

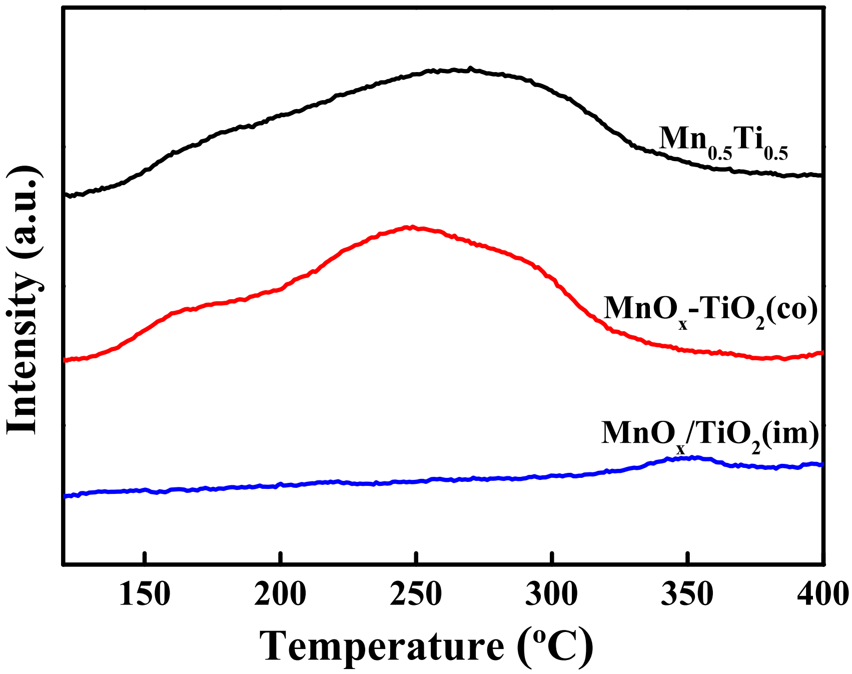


Fig. S11 NH_3-TPD profiles of $Mn_{0.5}Ti_{0.5}$, MnO_x-TiO_2(co) and MnO_x/TiO_2(im) catalysts.

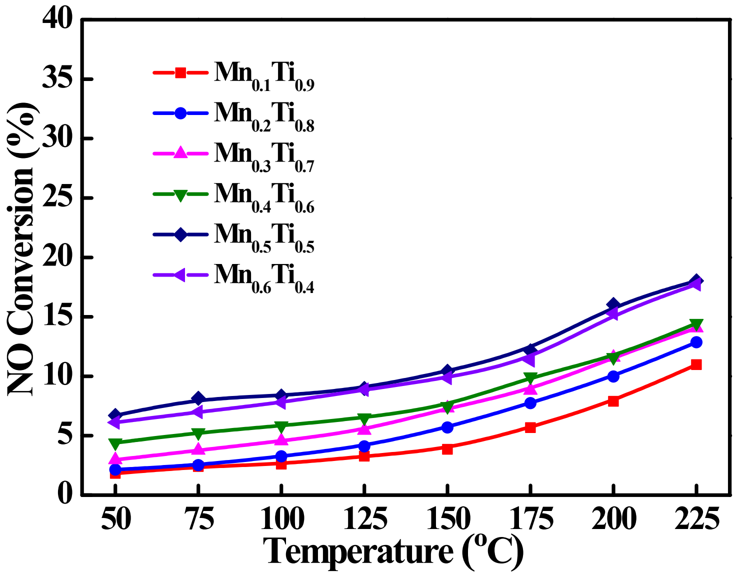


Fig. S12 NO oxidation activities to NO_2 over the Mn_aTi_{1-a} catalysts. Conditions: [NO] = 1000 ppm, [O_2] = 3 vol.% and N_2 as balance gas.

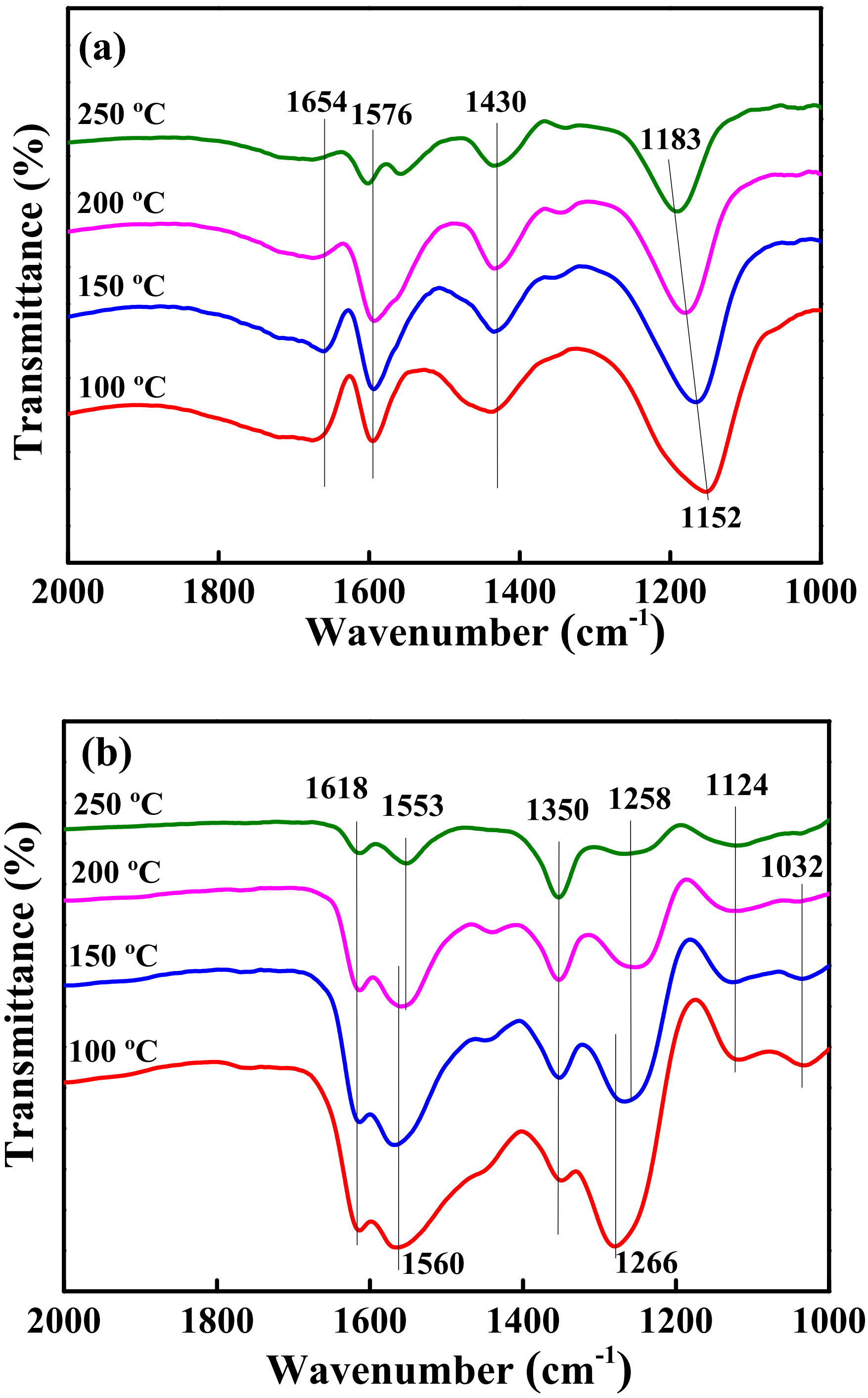
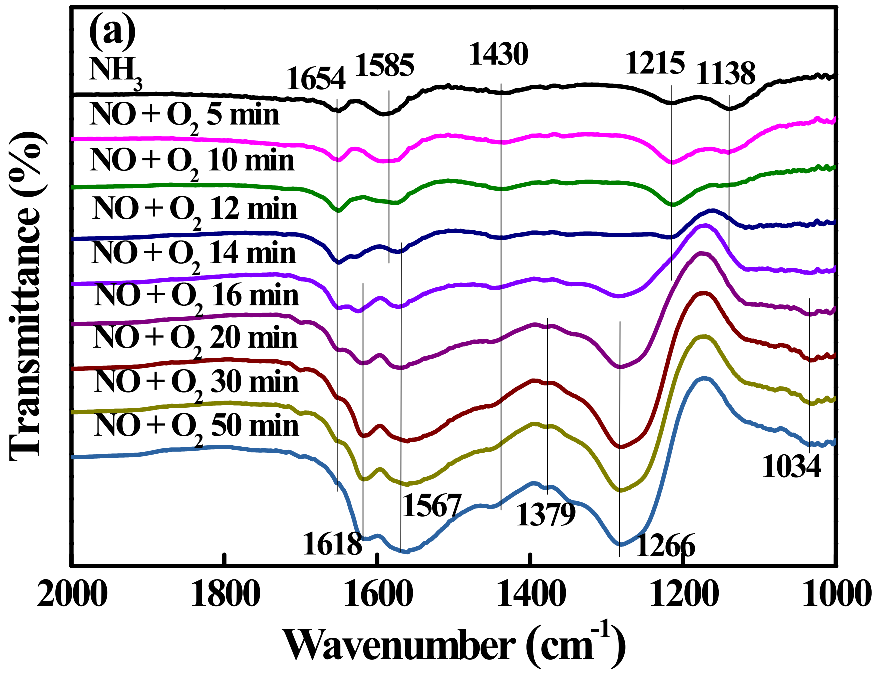


Fig. S13 *In-situ* FTIR spectra of (a) NH_3 and (b) NO + O_2 adsorption over the $Mn_{0.5}Ti_{0.5}$ catalyst at different temperatures. Conditions: [NH_3] = 1000 ppm (when used), [NO] = 1000 ppm (when used), [O_2] = 3 vol.% (when used), balance N_2.



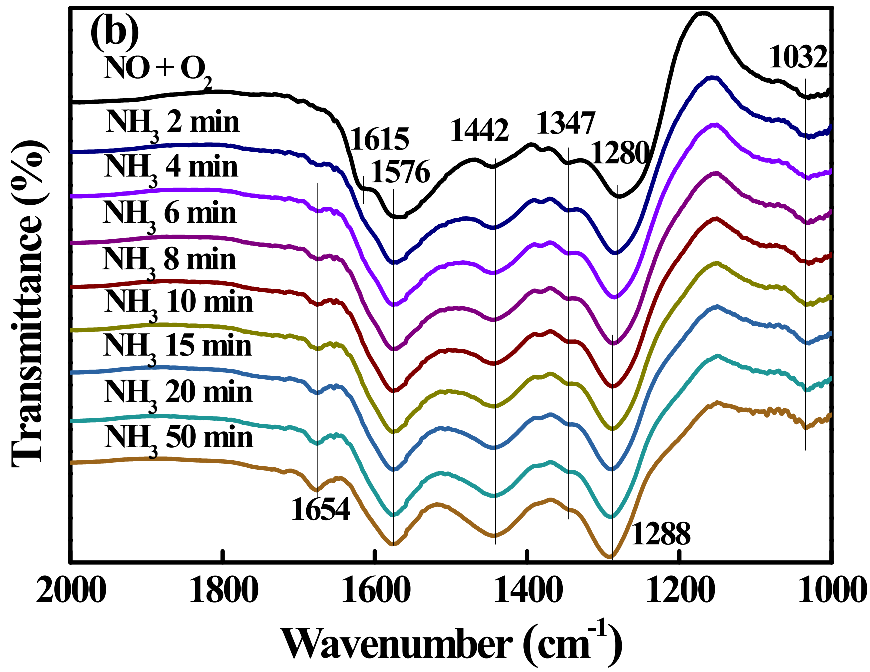


Fig. S14 *In-situ* FTIR spectra of (a) NO + O_2 reacted with pre-adsorbed NH_3 species and (b) NH_3 reacted with pre-adsorbed NO_x species over the $Mn_{0.5}Ti_{0.5}$ catalyst at 100 °C.

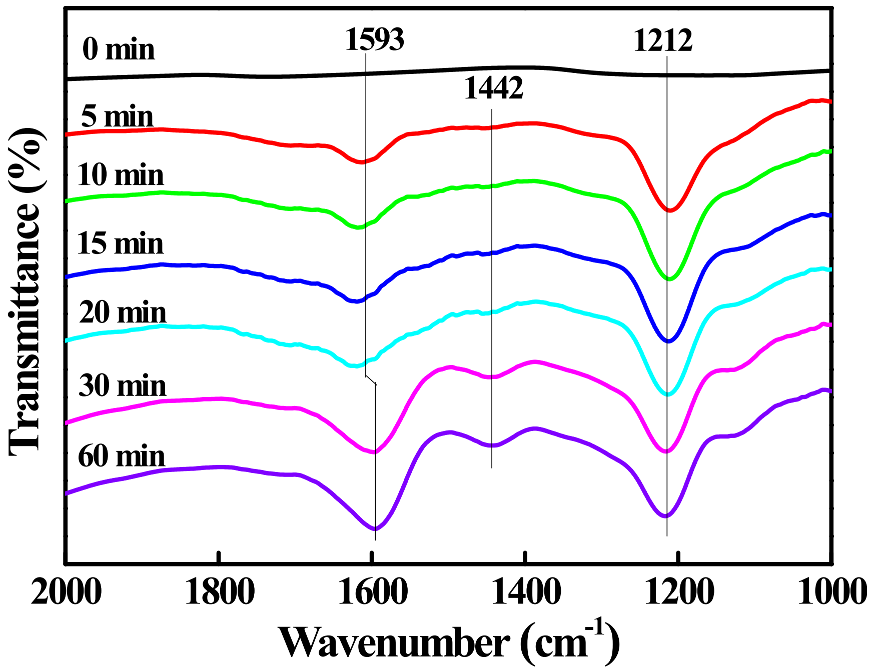


Fig. S15 *In-situ* FTIR spectra of NH_3 + NO + O_2 absorption over the $Mn_{0.5}Ti_{0.5}$ catalyst with different times at 150 °C. Conditions: [NH_3] = [NO] = 1000 ppm, [O_2] = 3 vol.%, balance N_2 at 150 °C.

Table S1 H_2 consumption and atomic ratio of $Mn_{a}Ti_{1-a}$ catalysts

Catalysts	H_2 consumption ($cm^3 \cdot g_{cat}^{-1}$)	Acid amount ($mmol \cdot g_{cat}^{-1}$)	Surface atomic concentration (%)			Atomic ratio (%)	
			Mn	O	Ti	$Mn^{4+}/(Mn^{4+}+Mn^{3+})$	$O_\alpha/(O_\alpha+O_\beta)$
$Mn_{0.5}Ti_{0.5}$	69.46	0.37	13.34	71.48	15.18	46.30	23.87
MnO_x-TiO_2(co)	68.03	0.32	10.05	75.35	14.60	33.71	32.06
MnO_x/TiO_2(im)	59.03	0.01	11.53	71.91	16.56	30.48	26.92