

**Enhancing effect of Cu and Sn doping on low-temperature catalytic activity and
operating temperature window of γ -Fe₂O₃ in NH₃-SCR of NO_x**

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Catalyst characterizations

The specific surface areas of catalysts was tested on a adsorption equipment (3H-2000PS1, Micromeritics, USA) at -196 °C and calculated by the BET method.

The SEM images of catalysts were acquired on FEI QUANTA FEG250 (FEI, USA) scanning electron microscope.

The XRD patterns of catalysts were achieved on a X-ray diffractometer (D8 Advance, Bruker, Germany) with Cu K α radiation.

Raman spectra of these catalysts were obtained on a Raman spectrometer (InVia, Renishaw, U.K.) with a 532 nm Ar⁺ laser beam at room temperature. The spectra were collected in the range of 100-800 cm⁻¹.

Ammonia temperature-programmed desorption (NH₃-TPD) tests were performed to evaluate surface acidity of catalysts on a chemisorption analyzer (MicrotracBEL BETCAT-A, Japan). After purged at 300 °C in He for 1 h, 200 mg catalyst was chilled to 50 °C, 30 mL/min of 1% NH₃-He was then introduced at this temperature until it was saturated. Next, He was injected to purge the gaseous NH₃. Lastly, the data were gained from 50 to 600 °C.

Hydrogen temperature-programmed reduction (H₂-TPR) experiments were executed on the same instrument of the NH₃-TPD test to estimate the redox capacity of these catalysts. Before the test, 50 mg catalyst underwent a one-hour purification process in N₂ at 350 °C, after which they were cooled to 100 °C. Afterward, the reduction experiments were executed from 100 to 600 °C in 30 mL/min of 10% H₂/Ar mixed gas and the data were recorded simultaneously.

The surface chemical information of different catalysts was obtained by X-ray photoelectron spectroscopy (XPS) measurements (ESCALAB 250Xi, Thermo Fisher, USA) using a radiation of Al K α . All the binding energies were calibrated using the C 1s peak at 284.6 eV.

The *in situ* DRIFT experiments were performed on a FTIR spectrometer (IS20, Nicolet, USA). Before the tests, each catalyst was purified in N₂ for one hour at 400 °C and the background spectra were recorded by cooling the temperature to 240 °C. After pretreating the catalysts for one hour with 1000 ppm NO+5% O₂/N₂ (1000 ppm NH₃/N₂), the gas was changed to 1000 ppm NH₃/N₂ (1000 ppm NO+5% O₂/N₂). Subsequently, the spectra were captured at various times by removing the background spectra automatically.

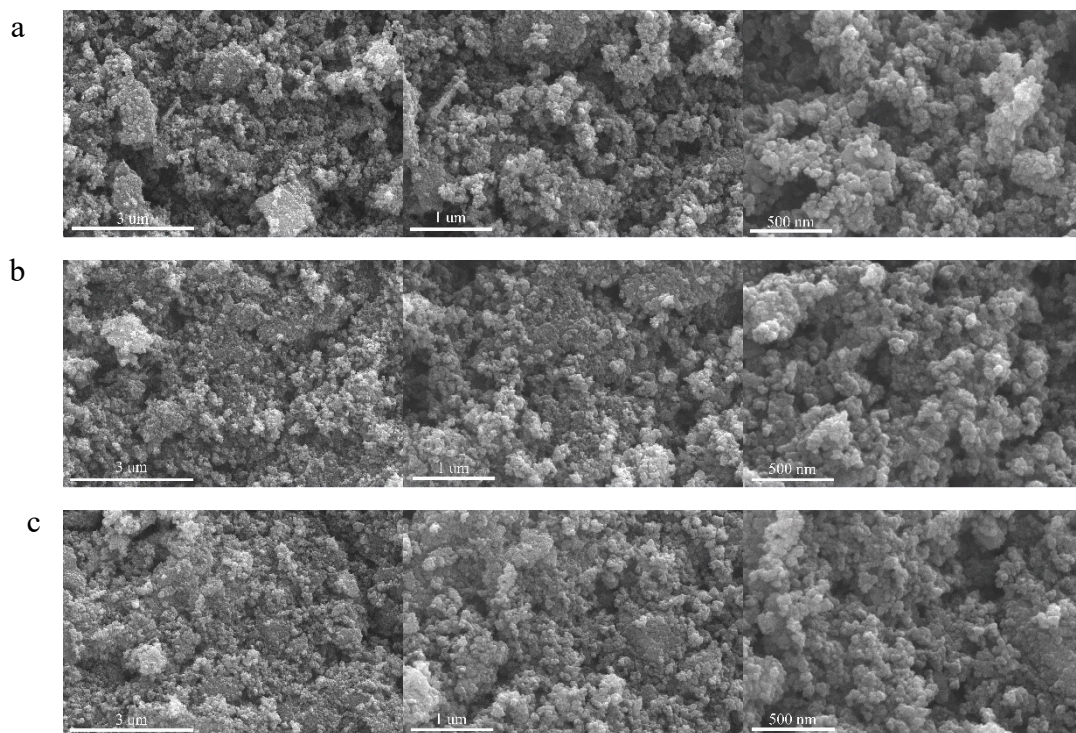


Fig. S1. SEM images of these catalysts: (a) $\gamma\text{-Fe}_2\text{O}_3$, (b) $\text{Cu}/\gamma\text{-Fe}$, and (c) $\text{Sn}/\gamma\text{-Fe}$.