Supporting information

Design ordered mesoporous confinement Pt/Ti$_{0.1}$AlO$_y$ catalysts for the propane catalytic combustion

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1. Catalyst characterizations

The TEM image was carried out on a JEOL JEM-2010 transmission electron microscope equipped operating at 200kV. For TEM analysis, the samples were uniformly dispersed in the ethanol solution, which was further installed on double-sided adhesive tape.

X-ray diffraction (XRD) analysis was conducted to explore the crystal phase of samples, which was recorded on a Rigaku D/MAX-RB X-ray diffractometer with Cu Kα radiation (λ = 1.5418 Å) and run in the range of 0.4-4 $^\circ$ with 60 kV and 55 mA.

N_2 adsorption-desorption was conducted on a Micromeritics ASAP 2010 instrument, and the specific surface area of the catalyst was determined by nitrogen adsorption in accordance with the Brunauer Emmett and Teller (BET) method. Before measurements, the sample was degassed at 150 $^\circ$C for 6 h, and BET surface area determination was calculated through six measurements at relative pressures of N_2 in the range of 0.05-1.00.

X-ray photoelectron spectroscopy (XPS) analysis was carried out on a VG ESCALAB 210 Electron Spectrometer using Mg Ka radiation (hv= 1253.6 eV) to determine the chemical states of elements in these samples.

To explore the formation of defect structure, A RM 2000 microscope confocal Raman spectrometer (Renishaw PLC) with a 532 nm laser was used.

The Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (ATR-FTIR) was recorded with VERTEX70 having a resolution of 4 cm^{-1}. Each sample was scanned at a range of 1000-3500 cm^{-1}.

Thought Bruker V70 collected in situ DRIFTS (In situ diffuse reflectance infrared fourier transform spectroscopy). Firstly, the 0.3% $Pt/Ti_{0.1}AlO_y$-EISA catalyst was handled in an N_2 atmosphere at 300 °C for 1h and then cooled to 50 °C. The flow rate was adjusted to 25 mL min^{-1}, and 0.2% propane was introduced continuously at 50 °C for 30 min. Thereafter, pure N_2 gas and a mixed reaction gas of 20% volume O_2 and 80% volume N_2 were introduced into in situ cell and reacted with toluene respectively. Finally, the samples were further heated to 100, 150, 200, 250, 300, and 350 °C to collect the corresponding spectra, respectively.

H_2-temperature program reduction (H_2-TPR) was performed by automatic multi-function adsorption apparatus. The mixed gas of 5 vol.% H_2 and 95 vol.% N_2 was introduced into the quartz tube reactor. After that, 0.1 g catalysts were put in the quartz tube reactor. Before the test, the catalysts were purged with pure N_2 gas at 100 °C for 1 h, and then the test was conducted from 100 °C to 800 °C with a heating rate of 10 °C/min.

O_2-temperature program desorption (O_2-TPD) was used to investigate the types of oxygen species in these samples. Firstly, 0.1 g catalysts were put into the quartz tube reactor, and then they were purged with pure N_2 gas at 100 °C for 1 h. After that, and then the pure He gas was used to remove the unabsorbed O_2 molecules at 30 °C for 1 h. Ultimately, the catalysts were heated from 100 °C to 900 °C.

Besides, to investigate the effect of acidity, NH_3-temperature program desorption (NH_3-TPD) was conducted by automatic multi-function adsorption apparatus. The 0.1 g catalysts were put in the quartz tube reactor and purged with pure N_2 gas at 100 °C

for 1 h, and then the adsorbing gas of 5 vol. % NH_3 and 95 vol. % N_2 was passed into the quartz tube reactor. Finally, the experiment was conducted from 100 °C to 800 °C.

2. Catalytic activity measurements

To evaluate the catalytic activity of the propane oxidation reaction, the experiments were carried out in a continuous-flow fixed-bed quartz tube microreactor. The reaction gas containing propane (2000 ppm) was through the reactor with a weight per hour spatial velocity (WHSV) of 60,000 mL g^{-1} h^{-1}. The catalysts were first pressed into flakes using a tablet press and then sieved into particles of uniform size using a 40-60 mesh sieve, and then a mixture of 0.2 g catalysts and 0.4 g quartz sand was added to the reactor with an inner diameter of 1 cm and a length of 30 cm. After that, the reaction temperature was increased to 300 °C and each temperature point was stabilized for one hour before sampling. The reactants and products were analyzed with a GC-9190I gas chromatograph and a flame ionization detector.

The conversion of propane was calculated by the following equation:

$$X_{propane} = \frac{[C]_{in} - [C]_{out}}{[C]_{in}} \times 100 \,\% \qquad (S1)$$

$X_{propane}$ indicates the conversion rate of propane.

$[C]_{in}$ indicates the inlet concentration of propane.

$[C]_{out}$ indicates the outlet concentration of propane.

The kinetic calculation of catalysts

The catalytic combustion of propane over $mPt/Ti_{0.1}AlO_y$-EISA and $0.3\%Pt/Ti_{0.1}AlO_y$-VI catalysts were passed for as a first-order reaction, and the activation energy can be calculated via the Arrhenius equation and the calculation

process is as follows:

$$r = \frac{F}{W}[-\ln(1 - X_{propane})] \qquad (S2)$$

In which $X_{propane}$, W and F represent the conversion rate of propane, catalyst weight, and the feed rate of propane, respectively. Eq. S5 is obtained from Eq. S3 and Eq. S4.

$$r = kC_{propane} \qquad (S3)$$

Where $C_{propane}$ and k denote the concentration in feed flow and the dynamics.

$$k = A \cdot \exp\left(-\frac{E_a}{RT}\right) \qquad (S4)$$

Where R, T, and Ea indicate gas constant, reaction temperature, and activation energy.

$$\ln r = -\frac{E_a}{RT} + B \qquad (S5)$$

where B means the constant. On the basis of Eq. S2 and Eq. S5, the relation between lnr and 1/T can be obtained, as shown in Fig. S3. The Values of the four samples are listed in Table S1.

The selectivity of CO_2 was calculated as follows:

$$CO_2 \text{ selectivity} = \frac{[CO_2]_{out}}{3 \times ([C]_{in} - [C]_{out})} \times 100\% \qquad (S6)$$

$[CO_2]_{out}$ indicated the outlet concentration of CO_2.

Table S1 The catalytic performance results of mPt/Ti$_{0.1}$AlO$_y$-EISA catalysts.

Catalysts	T$_{10}$ (°C)	T$_{50}$ (°C)	T$_{90}$ (°C)	Ea (kJ·mol^{-1})
0.2%Pt/Ti$_{0.1}$AlO$_y$-EISA	353	425	534	84.37
0.3%Pt/Ti$_{0.1}$AlO$_y$-EISA	340	412	494	60.76
0.5%Pt/Ti$_{0.1}$AlO$_y$-EISA	343	454	579	85.21

Table S2 The number of surface acids over mPt/Ti$_{0.1}$AlO$_y$-EISA catalysts.

Catalysts	Weak acid area	Medium acid area	Strong acid area	Total acid area
0.2%Pt/Ti$_{0.1}$AlO$_y$-EISA	263	301	478	1042
0.3%Pt/Ti$_{0.1}$AlO$_y$-EISA	322	341	571	1234
0.5%Pt/Ti$_{0.1}$AlO$_y$-EISA	254	854	229	1337

Table S3 Surface area, pore volume, and average pore size of $0.3\%Pt/Ti_{0.1}AlO_y$-EISA, $0.3\%Pt/Ti_{0.1}AlO_y$-VI, and the $Ti_{0.1}AlO_y$ support.

Catalysts	BET surface area $(m^2 \cdot g^{-1})$	Average pore size (nm)	Pore volume $(cm^3 \cdot g^{-1})$
$0.3\%Pt/Ti_{0.1}AlO_y$-EISA	228.6	11.3	0.64
$0.3\%Pt/Ti_{0.1}AlO_y$-VI	311.4	6.5	0.51
$Ti_{0.1}AlO_y$ support	253.7	9.9	0.62

Table S4 The catalytic performance results of 0.3%Pt/Ti$_{0.1}$AlO$_y$-EISA

and 0.3%Pt/Ti$_{0.1}$AlO$_y$-VI catalysts.

Catalysts	T$_{10}$ (°C)	T$_{50}$ (°C)	T$_{90}$ (°C)	Ea (kJ·mol^{-1})
0.3% Pt/Ti$_{0.1}$AlO$_y$-EISA	340	412	494	60.76
0.3% Pt/Ti$_{0.1}$AlO$_y$-VI	348	462	548	85.04

Table S5 The number of surface acids over $0.3\%Pt/Ti_{0.1}AlO_y$-EISA and $0.3\%Pt/Ti_{0.1}AlO_y$-VI catalysts.

Catalysts	Weak acid area (percentage)	Medium acid area (percentage)	Strong acid area (percentage)	Total acid area (percentage)
$0.3\%Pt/Ti_{0.1}AlO_y$-EISA	322 (26.10%)	341 (27.63%)	571 (46.27%)	1234 (100%)
$0.3\%Pt/Ti_{0.1}AlO_y$-VI	314 (26.04%)	318 (26.37%)	574 (47.59%)	1206 (100%)

Table S6 XPS analysis of $0.3\%Pt/Ti_{0.1}AlO_y$-EISA and $0.3\%Pt/Ti_{0.1}AlO_y$-VI catalysts.

Catalysts	$Pt^{2+}/(Pt^{2+}+Pt^{4+})$	$Pt^{4+}/(Pt^{2+}+Pt^{4+})$	O_{latt}/O_{total}	O_{ads}/O_{total}
	(%)	(%)	(%)	(%)
0.3% $Pt/Ti_{0.1}AlO_y$-EISA	56.24	43.76	53.84	46.16
0.3% $Pt/Ti_{0.1}AlO_y$-VI	55.23	44.77	82.40	17.60

Table S7 XPS analysis after sulfur resistance of $0.3\%Pt/Ti_{0.1}AlO_y$-EISA and $0.3\%Pt/Ti_{0.1}AlO_y$-VI catalysts.

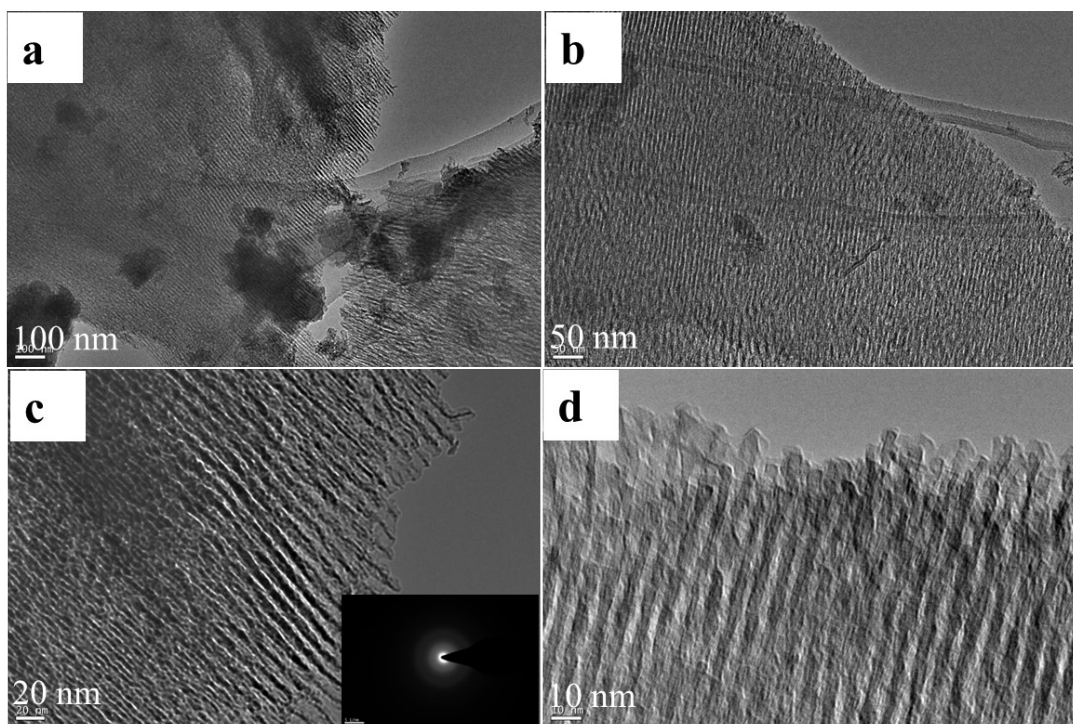| Catalysts	$Pt^{2+}/(Pt^{2+}+Pt^{4+})$ (%)	$Pt^{4+}/(Pt^{2+}+Pt^{4+})$ (%)	O_{latt}/O_{total} (%)	O_{ads}/O_{total} (%)
$0.3\%Pt/Ti_{0.1}AlO_y$-EISA	57.97	42.03	59.51	40.49
$0.3\% Pt/Ti_{0.1}AlO_y$-VI	55.24	44.76	69.40	30.60

Fig. S1 TEM images of the $Ti_{0.1}AlO_y$ support: 100 nm (a), 50 nm (b), 20 nm (c), 10 nm (d).

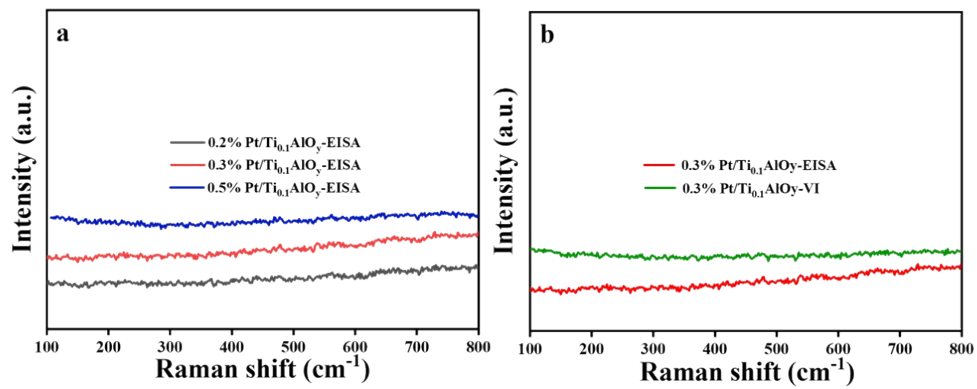**Fig. S2** Raman spectra of mPt/Ti$_{0.1}$AlO$_y$-EISA (a), 0.3%Pt/Ti$_{0.1}$AlO$_y$-EISA and

0.3%Pt/Ti$_{0.1}$AlO$_y$-VI catalysts (b).