Fabrication of Pd/CeO$_2$ nanocubes as highly efficient catalyst for degradation of formaldehyde at room temperature

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Physical characterizations

Pulse CO chemisorption: the CO pulse experiments were carried out with an AutoChem II 2920 apparatus equipped with a TCD detector. Firstly, the catalysts were pretreated at 400 °C for 30 min under He (50 mL min^{-1}) with a heating rate of 10 °C min^{-1} to remove physically adsorbed water and other impurities. Then, after the temperature was cooled to 50 °C, the samples were reduced under a stream of 10% H$_2$/Ar (50 mL min^{-1}) at 400 °C for 120 min with a heating rate of 10 °C min^{-1}, following by cooling to 45 °C under He (50 mL min^{-1}). When the baseline was stabilized, 10% CO/He was used for CO pulse adsorption. The stoichiometry factor for Pd/CO was assumed to be 1 when calculating the metal dispersion.

Electron spin resonance (ESR) measurement: the electron spin resonance signals were characterized on a Bruker A300 ESR instrument at the X-band frequency with a microwave of 1.0 mW at room temperature.

H$_2$ temperature-programmed reduction (H$_2$-TPR): the H$_2$-TPR measurement were conducted with an AutoChem II 2920 apparatus equipped with a TCD detector. Firstly, the catalysts were pretreated at 400 °C for 30 min under He (50 mL min^{-1}) with a heating rate of 10 °C min^{-1}. Then, a mixture of 10% H$_2$/Ar (50 mL min^{-1}) gas was introduced when the samples were cooled to 50 °C. After stabilizing the baseline, the samples were heated to 400 °C at 10 °C min^{-1}.

O$_2$ temperature-programmed desorption (O$_2$-TPD): the O$_2$-TPD measurement were conducted with an AutoChem II 2920 apparatus equipped with a TCD detector. Firstly, the catalysts were pretreated at 400 °C for 30 min under He (50 mL min^{-1}) with a heating rate of 10 °C min^{-1}. After the samples were cooled to 50 °C, a mixture of 3% O$_2$/He (50 mL min^{-1}) gas was introduced and kept for 60 min. Then, He (50 mL min^{-1}) was injected for 60 min. When the baseline was stabilized, the samples were hearted to 500 °C at 10 °C min^{-1}.
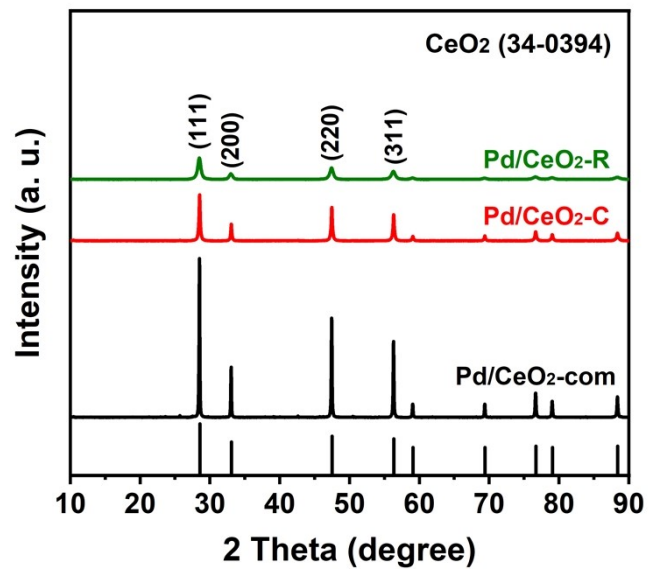
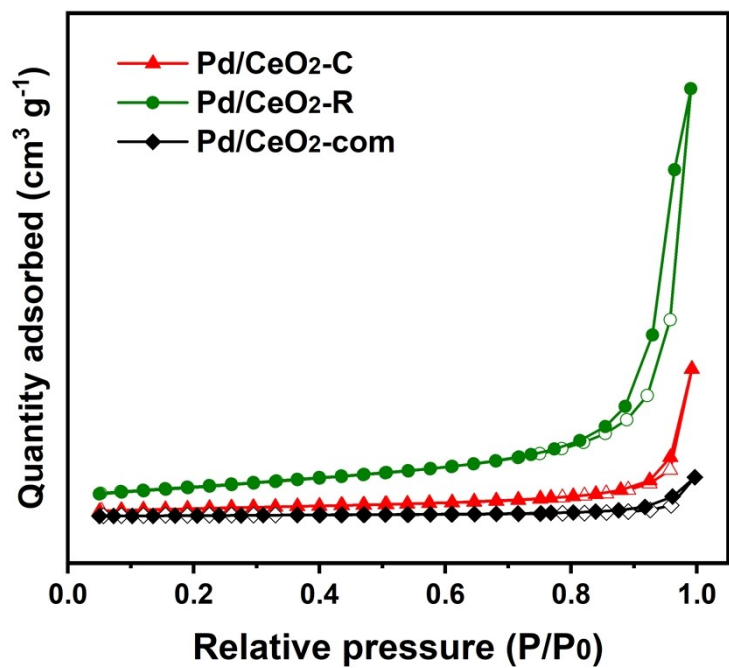Fig. S1. The XRD patterns of Pd/CeO$_2$-C, Pd/CeO$_2$-R and Pd/CeO$_2$-com catalysts.

Fig. S2. N$_2$ adsorption-desorption isotherm plots of Pd/CeO$_2$-C, Pd/CeO$_2$-R and Pd/CeO$_2$-com catalysts.
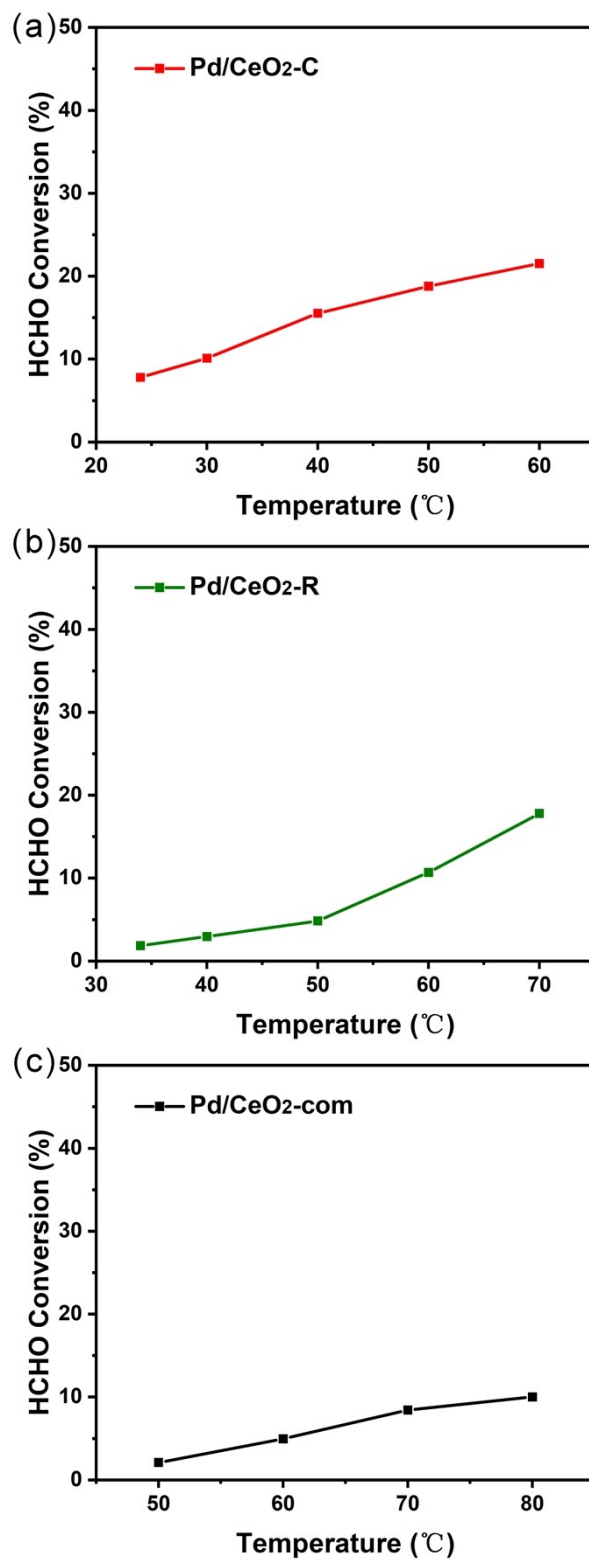
Fig. S3. The kinetic measurement of (a) Pd/CeO$_2$-R, (b) Pd/CeO$_2$-R, (c) Pd/CeO$_2$-com catalysts. The kinetic data were collected at the HCHO conversion below 20% and the reaction rate (r_{HCHO}) was calculated by Eq. (4).
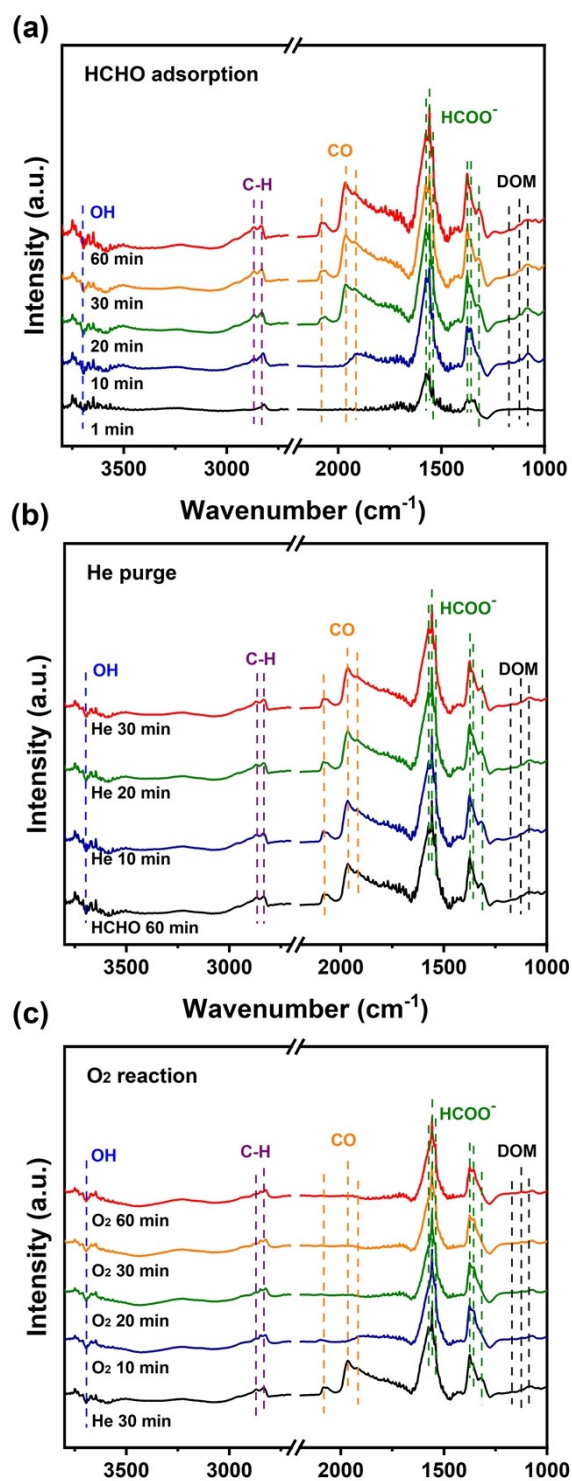
Fig. S4. *In situ* DRIFT spectra (including wavenumber > 2500 cm^{-1}) of HCHO reaction process on Pd/CeO$_2$-C catalyst: (a) the adsorption process of HCHO; (b) He purging process; (c) O$_2$ reaction process.

Table S1. Performance comparison of HCHO oxidation between Pd/CeO$_2$-C catalyst and published results.

Catalyst	Pd loading (wt.%)	Reaction condition	Conversion (%)	Ref
Pd/TiO$_2$	1	120 ppm HCHO, 25 °C GHSV=100000 h^{-1}	100	[1]
Pd/KTO-NB	1	140 ppm HCHO, 25 °C GHSV=20000 h^{-1}	100	[2]
Pd/TiO$_2$	0.5	100 ppm HCHO, 30 °C WHSV=120000 mL g h^{-1}	100	[3]
Pd/@TS-1	0.2	100 ppm HCHO, 25 °C WHSV=100000 mL g h^{-1}	100	[4]
Pd/TiO$_2$	1	100 ppm HCHO, 25 °C WHSV=300000 mL g h^{-1}	100	[5]
Pd/γ-Al$_2$O$_3$	0.78	160 ppm HCHO, 25 °C WHSV=100000 mL g h^{-1}	100	[6]
Pd/TiO$_2$	0.2	50 ppm HCHO, 25 °C WHSV=24000 mL g h^{-1}	100	[7]
Pd/CeO$_2$	1	100 ppm HCHO, 30 °C WHSV=150000 mL g h^{-1}	89	[8]
Pd/CeO$_2$	1	100 ppm HCHO, 30 °C WHSV=150000 mL g h^{-1}	76	[9]
Pd/TiO$_2$	1	140 ppm HCHO, 25 °C GHSV=95000 h^{-1}	100	[10]
Pd/CeO$_2$-C	0.64	200 ppm HCHO, 25 °C GHSV=36000 mL g h^{-1}	RT	This work

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