Electronic Supplementary Information (ESI):

Low-temperature Catalytic Oxidation of CO over Highly Active Mesoporous Pd/CeO_2-ZrO_2-Al_2O_3 Catalyst

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S 1 catalysts preparation and Characterization

S 1.1 Preparation of CeO_2-ZrO_2-Al_2O_3-PVP, CeO_2-ZrO_2-Al_2O_3-P123 and CeO_2-ZrO_2-Al_2O_3-CTAB

3.5 g of the surfactant (one of the PVP, P123 or CTAB), 0.009 mol of cerium nitrate, 0.009 mol of zirconium nitrate, 0.002 mol of aluminum nitrate and urea (0.08 mol) were sequentially dissolved into 200 ml of deionized water at 60 °C. The resulted solution was then transferred to stainless steel Teflon-lined autoclaves and heated at 140 °C for 12 h. The final products were washed with distilled water, dried at 100 °C and calcined at 425 °C for 3 h in static air with heating rate of 3 °C/min. As-prepared solids are denoted with CeO_2-ZrO_2-Al_2O_3-PVP, CeO_2-ZrO_2-Al_2O_3-P123, and CeO_2-ZrO_2-Al_2O_3-CTAB respectively.

S 1.2 Preparation of Pd/CeO_2-ZrO_2-Al_2O_3-PVP, Pd/CeO_2-ZrO_2-Al_2O_3-P123 and Pd/CeO_2-ZrO_2-Al_2O_3-CTAB

CeO_2-ZrO_2-Al_2O_3-PVP, CeO_2-ZrO_2-Al_2O_3-P123, and CeO_2-ZrO_2-Al_2O_3-CTAB supported Pd catalysts were prepared by the wet impregnation method using aqueous solution of palladium nitrate as precursor with Pd content of 1% (wt %). The impregnated samples were dried at 60 °C and calcined at 350 °C for 2 h. The catalysts are denoted as Pd/CeO_2-ZrO_2-Al_2O_3-PVP, Pd/CeO_2-ZrO_2-Al_2O_3-P123, and Pd/CeO_2-

ZrO_2-Al_2O_3-CTAB respectively.

S1.3 H_2-temperature programmed reduction (H_2-TPR) analyses

H_2-temperature programmed reduction (H_2-TPR) analyses were carried out in a quartz tube reactor (i.d. 3.0 mm). 50 mg of the samples (60 - 80 mesh) was pre-treated under N_2 flow at 350 °C for 1 h and then cooled to room temperature. The N_2 flow was then shifted to the flow of H_2/Ar (5 vol. % of H_2, 30 ml/min) to balance for a while. The quartz tube reactor was heated with a linear heating rate of 8 °C/min. A thermal conductivity detector (TCD) was used to record the consumption of H_2 signals.

S 2 Results and Discussions

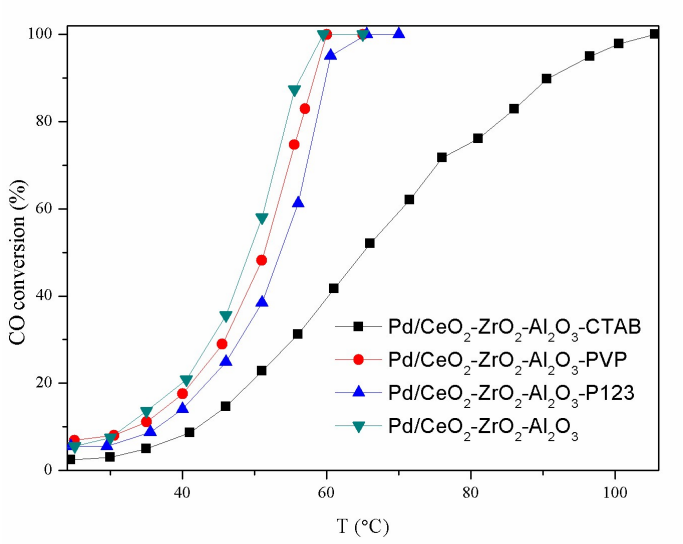

Fig. S1 catalytic activity of CO conversion over different samples (1.0 vol. % CO, 10.5 vol. % O_2, N_2 balanced, with the total flow rate of 50 ml/min and GHSV of 15000 $ml \cdot g^{-1} \cdot h^{-1}$**)**

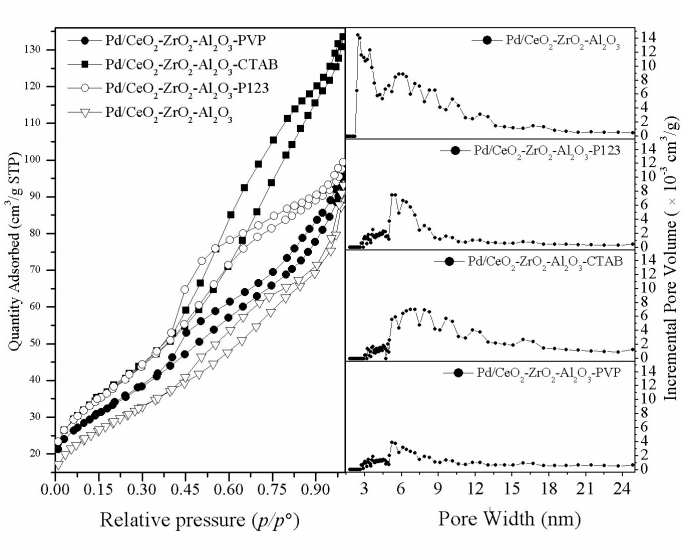

Fig. S2 N_2-adsorption and desorption isotherms and NL-DFT pore size distributions over Pd/CeO_2-ZrO_2-Al_2O_3 prepared from different commercial surfactants.

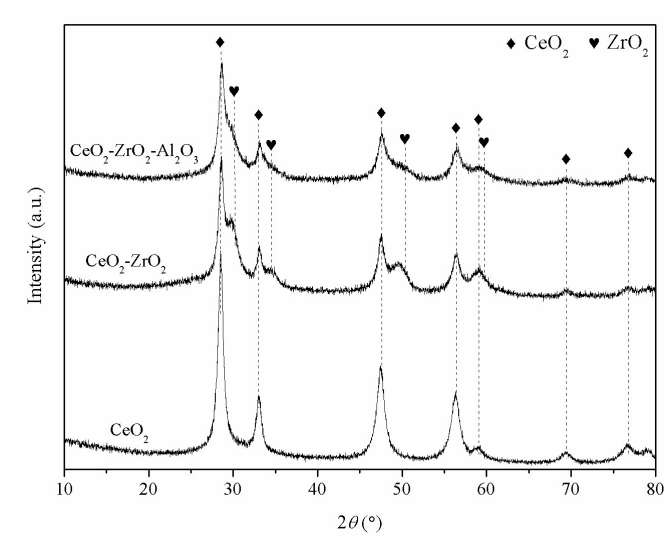

Fig. S3 XRD patterns of various parent supports.

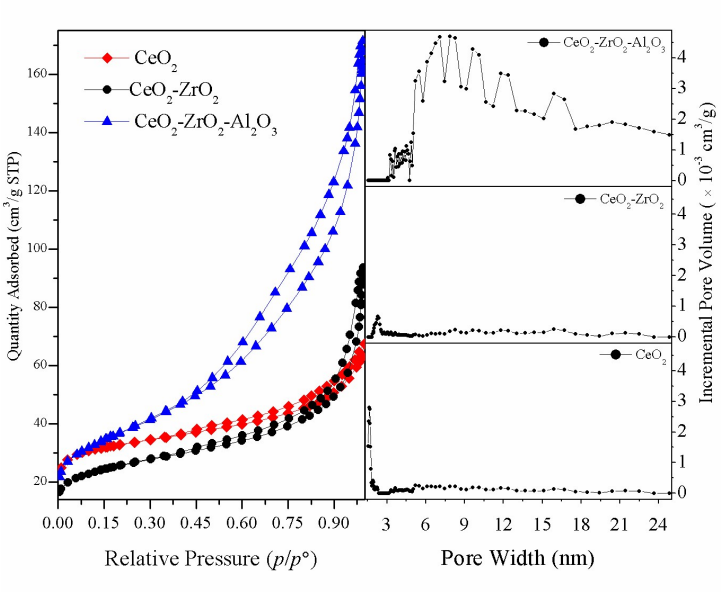

Fig. S4 N_2 adsorption-desorption isotherms and pore size distribution of various parent supports.

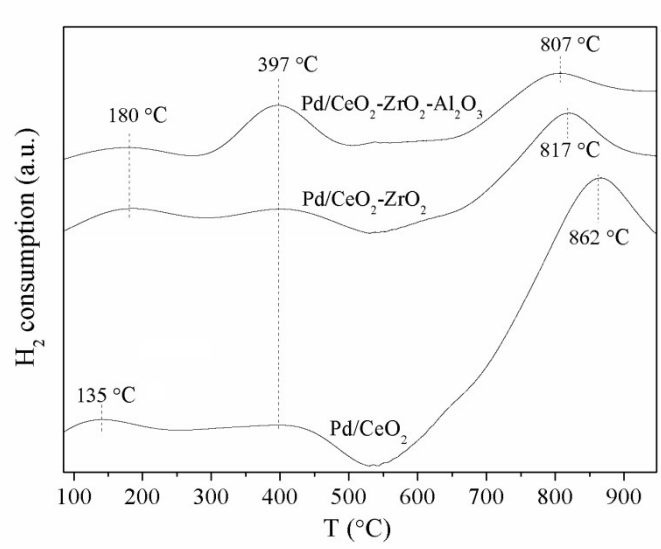

Fig. S5 H_2-TPR profiles of the various catalysts.

Table S1 Volumes of micropore, mesorpore and total pore volumes

Samples	Micropore volumes [a] (cm^3/g)	Mesorpore volumes [b] (cm^3/g)	Total pore volumes [c] (cm^3/g)
Pd/CeO_2	0.0394	0.0446	0.0949
Pd/CeO_2-ZrO_2	0.0384	0.0766	0.133
Pd/CeO_2-ZrO_2-Al_2O_3	0.0258	0.101	0.144

[a] Calculated from pore volumes in pore size < 1.987 nm by NL-DFT method.

[b] Calculated from pore volumes in pore size between 1.987 and 45 nm by NL-DFT method.

[c] Single point adsorption total pore volume of pore diameters less than 189 nm at p/p^0 = 0.995

Table S2 Proportion of micropore and mesorpore

Samples	R_{micro} [a] (%)	$R_{micro/total}$ [b] (%)	$R_{mesor/total}$ [c] (%)
Pd/CeO_2	46.93	41.55	46.99
Pd/CeO_2-ZrO_2	33.38	28.88	57.63
Pd/CeO_2-ZrO_2-Al_2O_3	20.35	17.92	70.14

[a] $R_{micro} = \frac{\text{micropore volumes}}{\text{micropore volumes} + \text{mesorpore volumes}} \times 100$

[b] $R_{micro/total} = \frac{\text{micropore volumes}}{\text{Total pore volumes}} \times 100$

[c] $R_{mesro/total} = \frac{\text{mesorpore volumes}}{\text{Total pore volumes}} \times 100$

Table S3 Total pore volume, SSA and pore size over different samples with the same composition

Samples	Total pore volume [a] (cm^3/g)	SSA (m^2/g)	Average pore [b] size (nm)
Pd/CeO_2-ZrO_2-Al_2O_3-PVP	0.148	103	5.7
Pd/CeO_2-ZrO_2-Al_2O_3-CTAB	0.207	122	6.7
Pd/CeO_2-ZrO_2-Al_2O_3-P123	0.155	121	5.2
Pd/CeO_2-ZrO_2-Al_2O_3	0.144	105	5.5

[a] calculated from Adsorption average pore diameter (4V/A) by BET

[b] Single point adsorption total pore volume of pore diameters less than 189 nm at p/p^0 = 0.995

Table S4 Surface atomic concentration over different samples

Samples	Surface atomic concentration (%)				
	O	Al	Zr	Pd	Ce
Pd/CeO_2-ZrO_2-Al_2O_3	63.36	4.79	10.14	0 [a]	21.71
Pd/CeO_2-ZrO_2	66.36	-	19.96	0 [a]	13.68
Pd/CeO_2	63.67	-	-	1.98	34.35

[a] Surface Pd species over Pd/CeO_2-ZrO_2 and Pd/CeO_2-ZrO_2-Al_2O_3 could not be quantitively analyzed as XPS peaks of Pd 3d and Zr 3p orbitals are much close.

Comparing with XPS peaks of Pd 3d orbital, influence of higher intensity of Zr 3p orbital makes it hard to quantitively analyze surface atomic concentration of surface palladium species.