Supporting information

High-temperature Flame Spray Pyrolysis Induced Stabilization of Pt Single-Atom Catalysts

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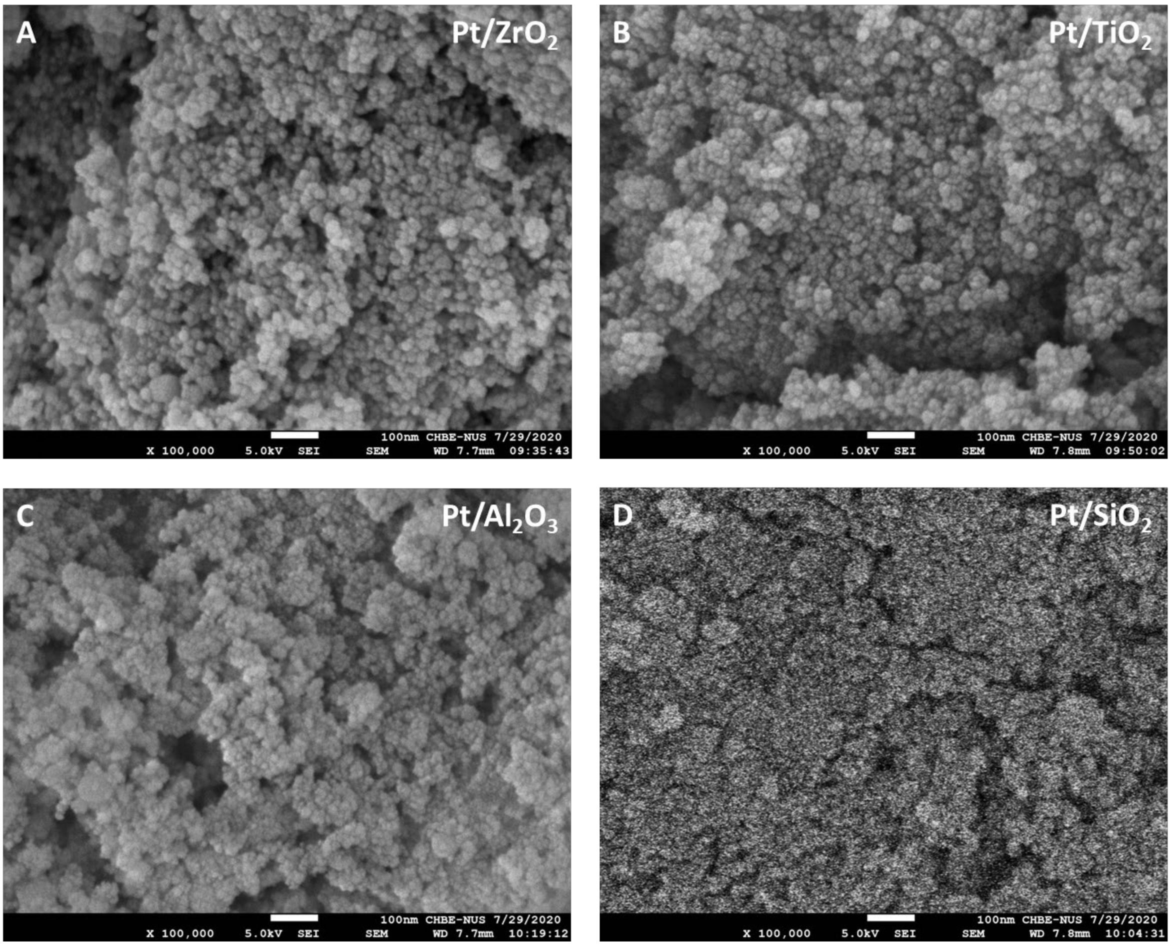

Fig. S1 The SEM images of the freshly prepared (A) $0.2Pt/ZrO_2$ (B) $0.2Pt/TiO_2$ (C) $0.2Pt/Al_2O_3$ (D) $0.2Pt/SiO_2$ using flame spray pyrolysis.

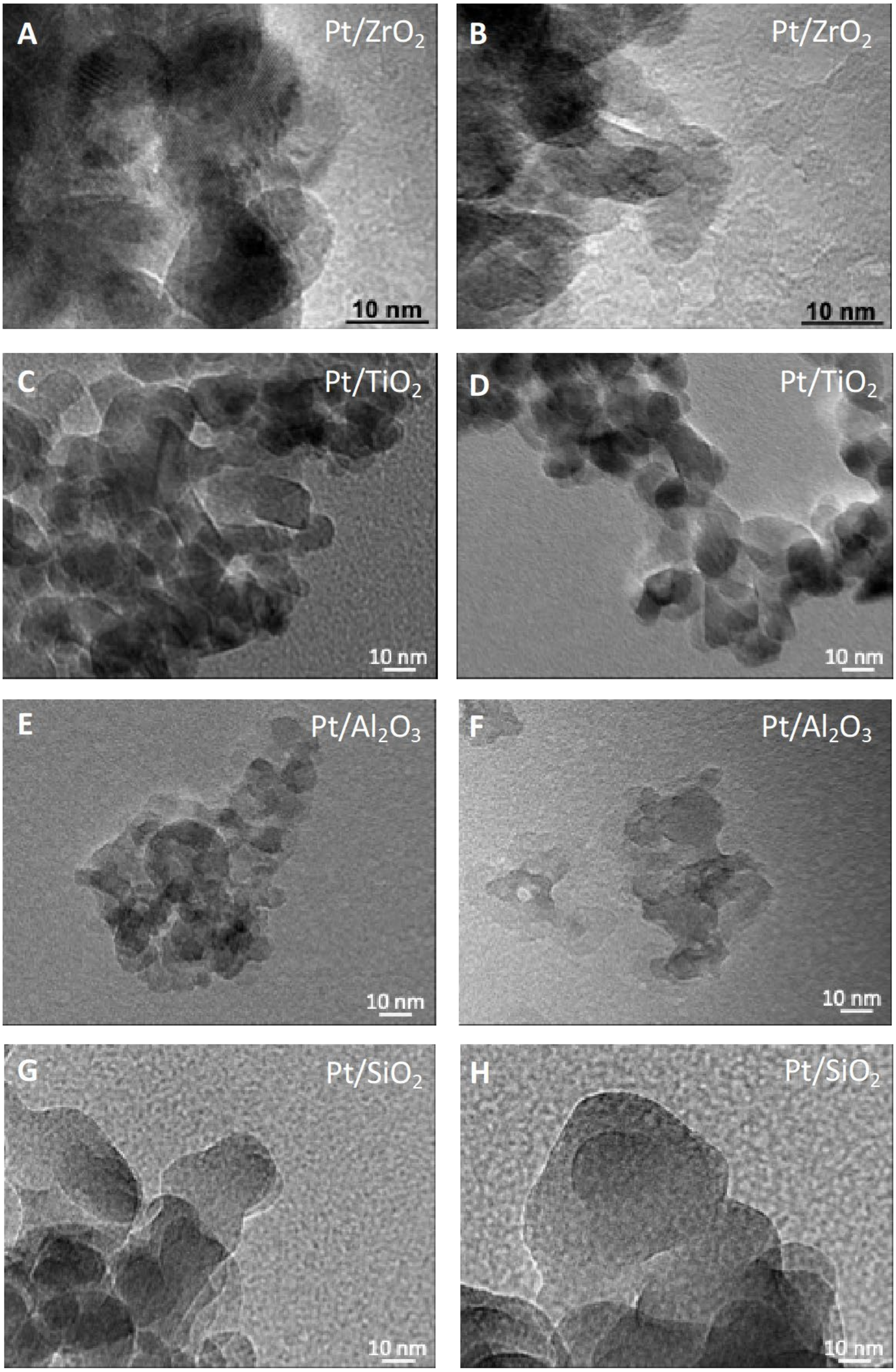

Fig. S2 The TEM images of (A-B) 0.2Pt/ZrO_2 (C-D) 0.2Pt/TiO_2 (E-F) 0.2Pt/Al_2O_3 (G-H) 0.2Pt/SiO_2 catalysts prepared by flame spray pyrolysis technique.

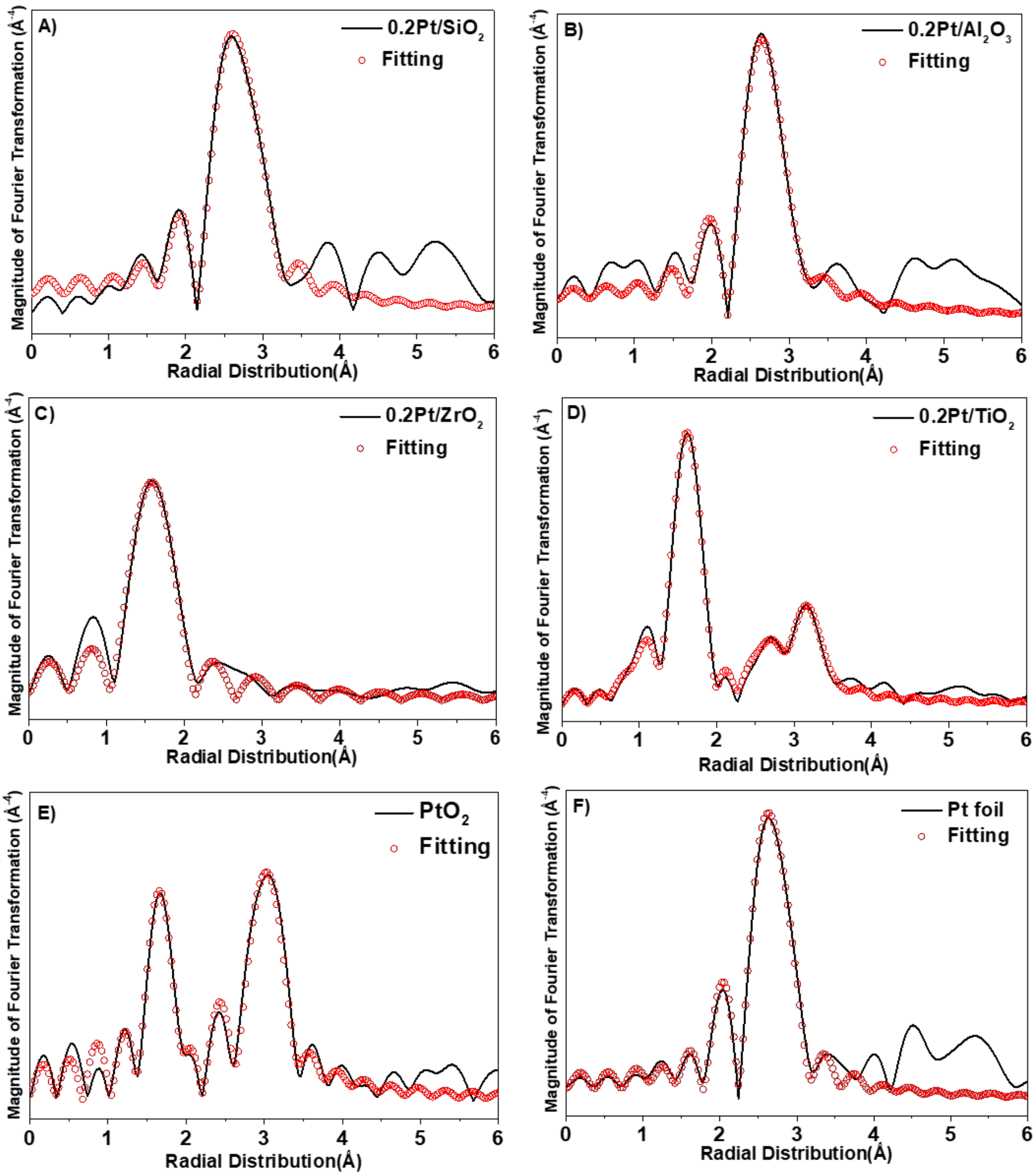

Fig. S3 The FT profiles of Pt L_3-edge k^3-weighted EXAFS and the fitting results of the samples prepared by flame spray pyrolysis and reference samples.

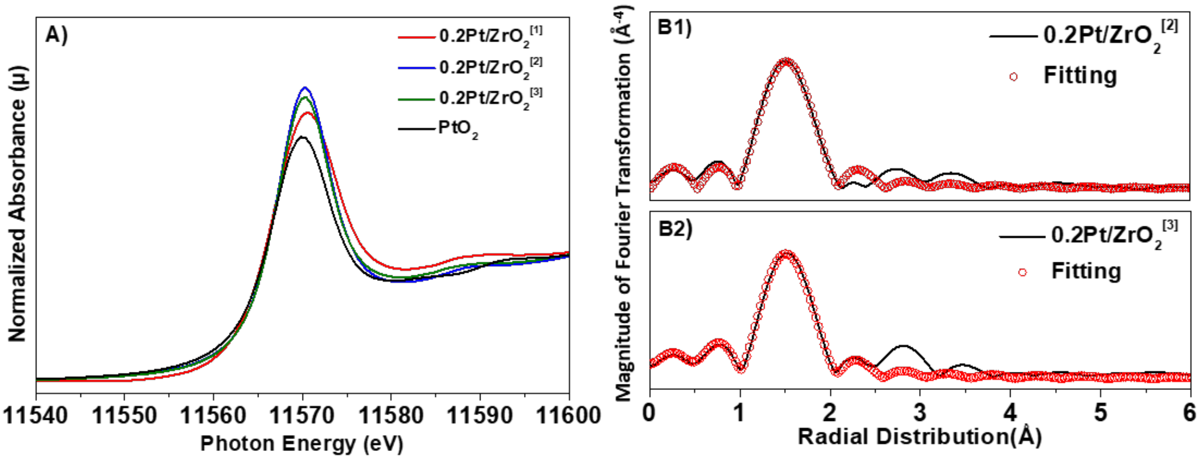

Fig. S4 (A) The normalized Pt L_3-edge XANES and (B1-B2) The FT profiles of k^3-weighted EXAFS of the 0.2Pt/ZrO_2. [2] and [3] represent 0.2Pt/ZrO_2 prepared under synthetic conditions 2) concentration 0.3 M, flow rate 3 mL/min; and 3) concentration 0.3 M, flow rate 2 mL/min, respectively.

Tab. S1. EXAFS parameters of Pt samples, Pt foil and PtO_2.

Samples	Shell	CN	R(Å)	$\Delta\sigma^2$ x 10^3($Å^2$)	ΔE_0(eV)	r-Factor(%)
Pt foil	Pt-Pt	12(fixed)	2.77	5.45	6.82	0.9
PtO_2	Pt-O	4.9	2.02	2.74	8.72	1.1
	Pt-Pt	5.0	3.10	2.63	8.95	
0.2Pt/ZrO_2[1]	Pt-O	4.3	1.99	0.10	7.90	0.7
0.2Pt/ZrO_2[2]	Pt-O	5.2	1.95	2.06	4.19	0.1
0.2Pt/ZrO_2[3]	Pt-O	4.4	1.96	0.12	4.18	0.04
0.2Pt/Al_2O_3	Pt-Pt	7.4	2.76	4.17	7.76	0.2
0.2Pt/SiO_2	Pt-Pt	8.1	2.76	3.75	7.06	0.7
0.2Pt/TiO_2	Pt-O	4.5	1.99	6.23	9.92	0.6

CN, coordination number; R, interatomic distance; σ^2, the Debye–Waller factor; ΔE_0, inner potential correction to account for the difference in the inner potential between the sample and each simulated path. [1], [2] and [3] represent 0.2Pt/ZrO_2 prepared under different preparation conditions (total metal concentration and flow rate of precursor solution): 1) concentration 0.5 M, flow rate 3 mL/min; 2) concentration 0.3 M, flow rate 3 mL/min; and 3) concentration 0.3 M, flow rate 2 mL/min.

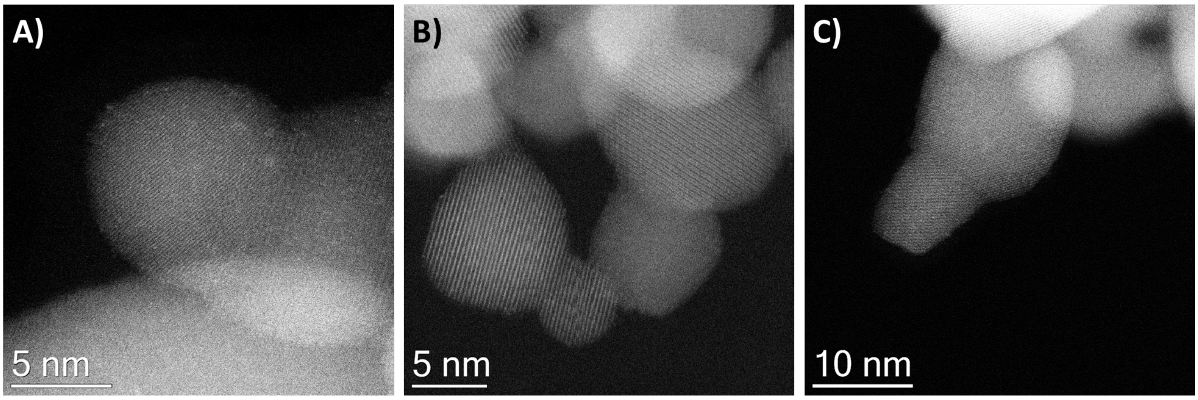

Fig. S5 HAADF-STEM images of the $0.1Pt_1/ZrO_2$-flame catalyst.

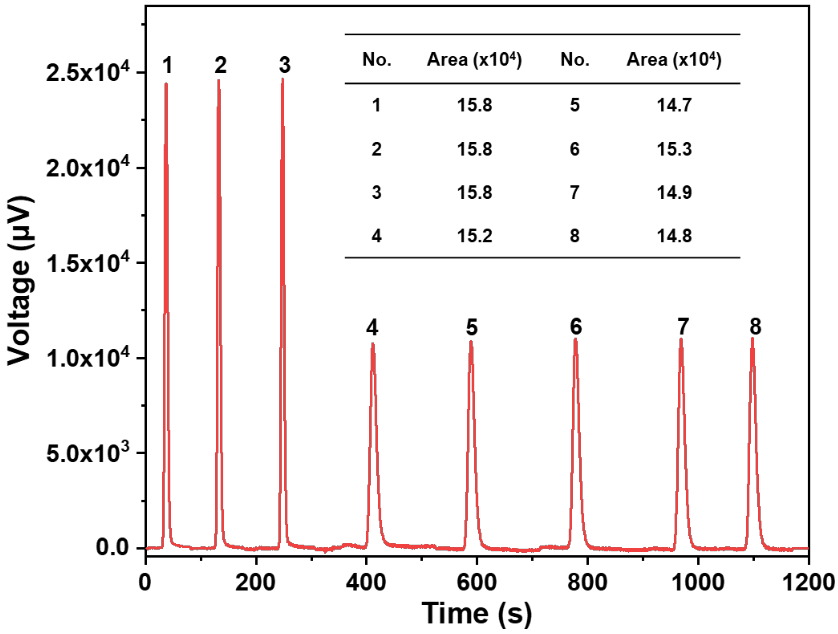

Fig. S6 H_2 titration file of $0.1Pt_1/ZrO_2$-flame. The inset is the integrated area of each peak. The first three peaks with the integrated area of $15.8X10^4$ indicate the control injections (no H_2 adsorption). No obvious H_2 uptake was observed when H_2 passed through the catalyst (from peak 4 to 8). Titration conditions: N_2 carrier gas, 100 ^oC, 0.2 mL 5% H_2/pulse, 62 mg catalyst.

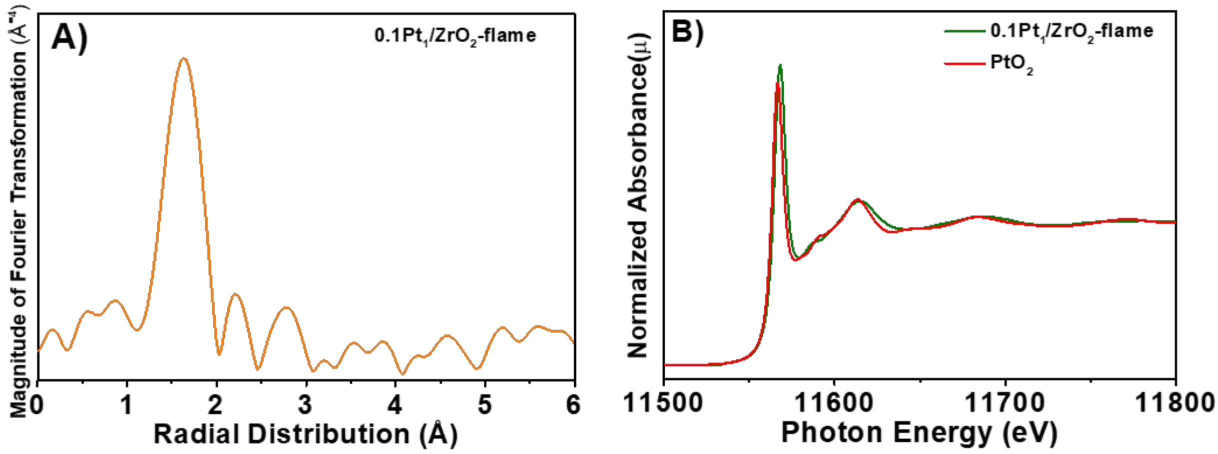

Fig. S7 (A) The FT profiles of k^3-weighted EXAFS and (B) the normalized XANES spectra at the Pt L_3-edge for $0.1Pt_1/ZrO_2$-flame and PtO_2.

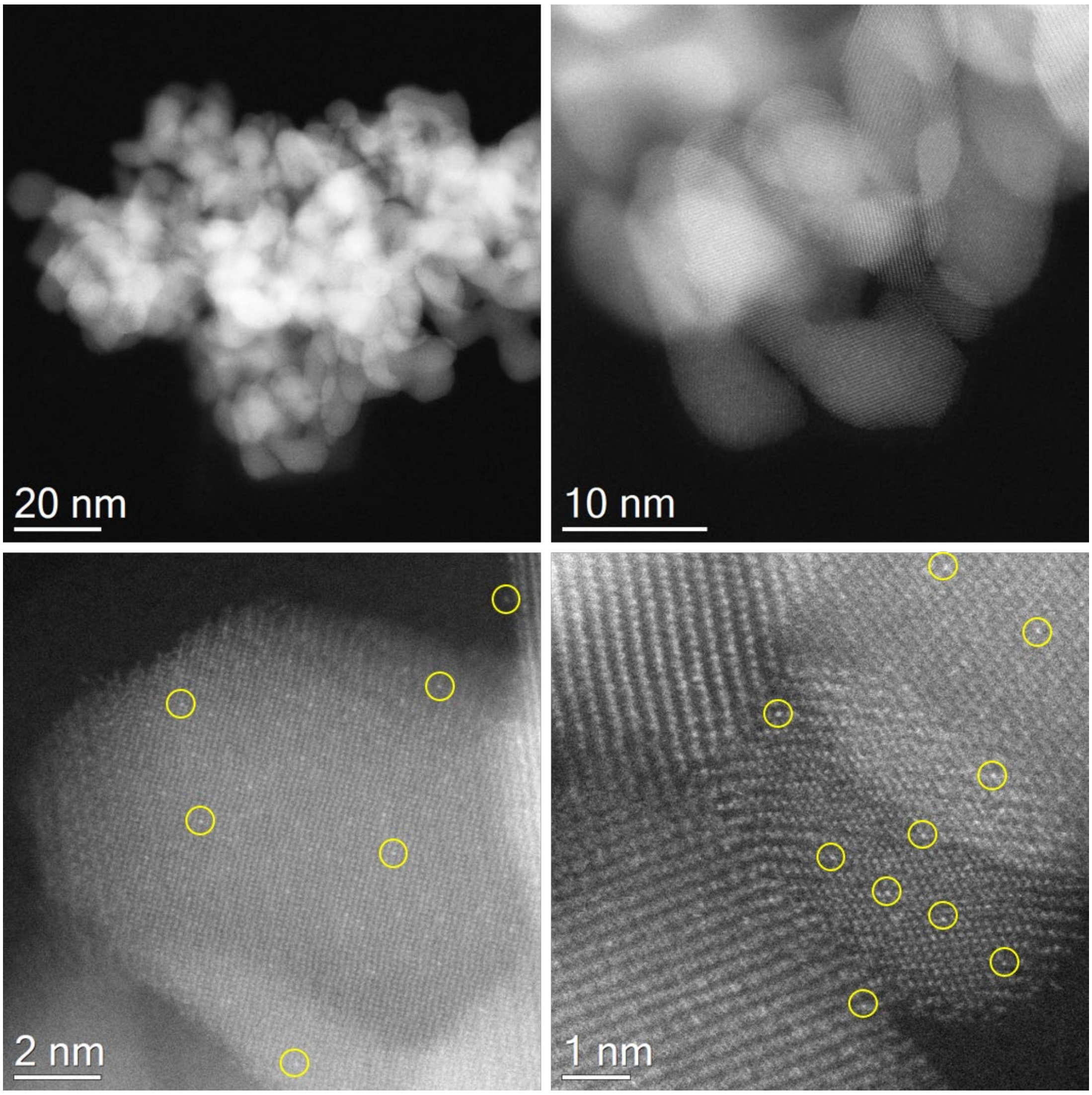

Fig. S8 Representative STEM-HAADF images of the $0.1Pt_1/ZrO_2$(m)-wet catalyst. Atomically dispersed Pt species are highlighted with yellow circles.

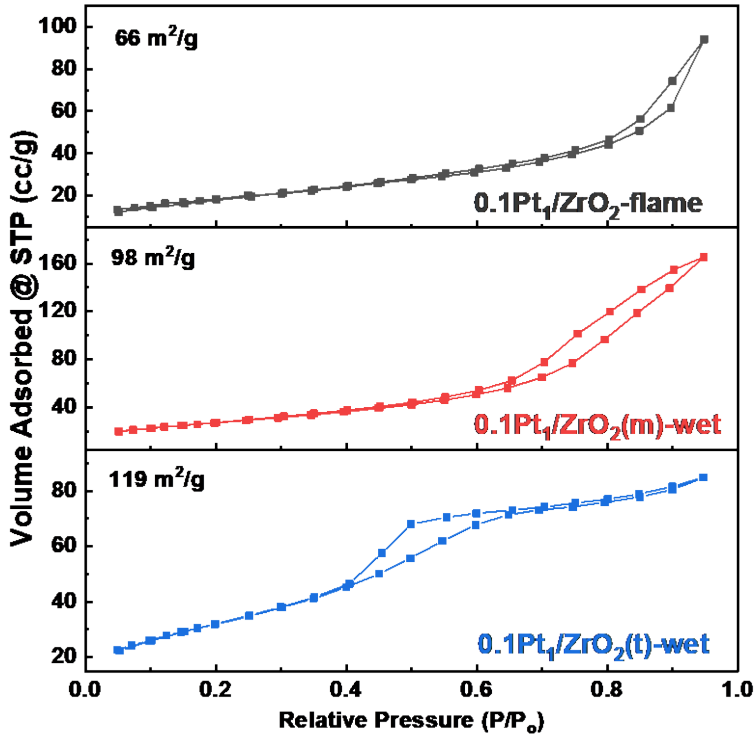

Fig. S9 N_2 adsorption/desorption isotherms of 0.1Pt_1/ZrO_2-flame, 0.1Pt_1/ZrO_2(m)-wet and 0.1Pt_1/ZrO_2(t)-wet.

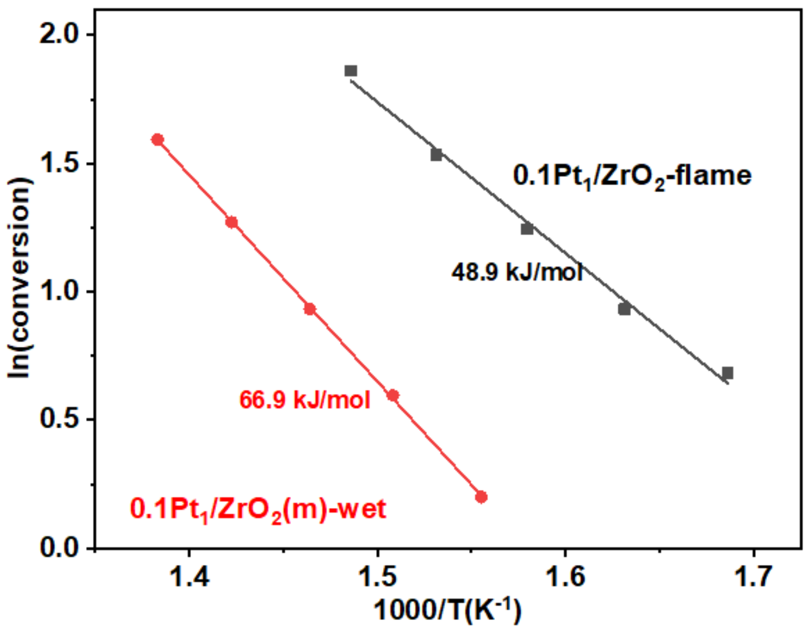

Fig. S10 Arrhenius plots of methane combustion reactions over 0.1Pt_1/ZrO_2-flame and 0.1Pt_1/ZrO_2(m)-flame.

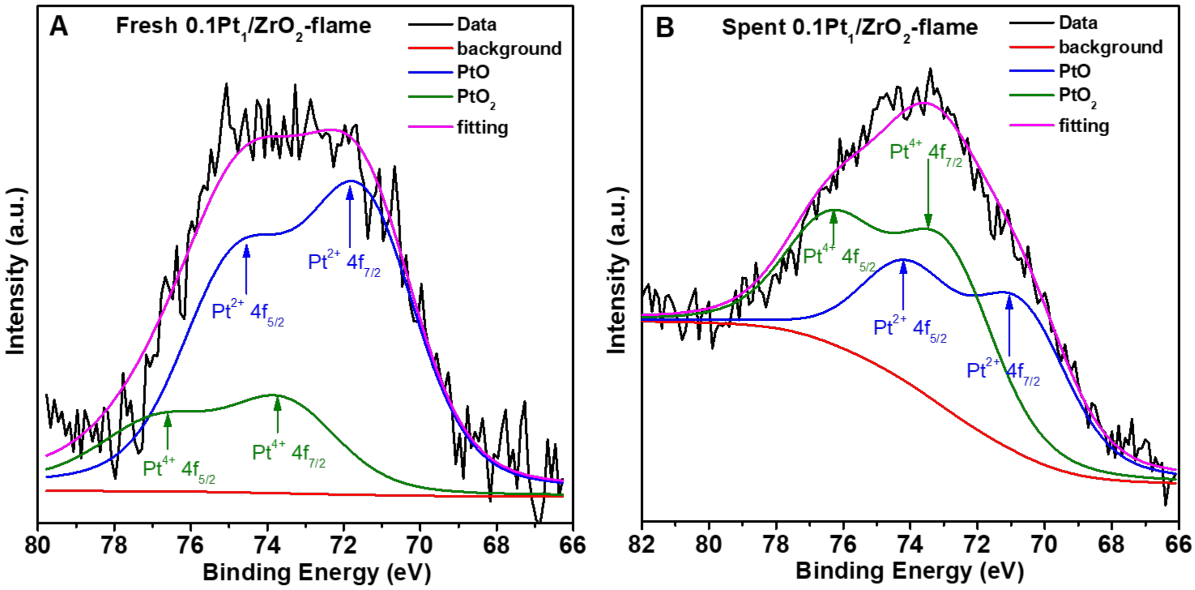

Fig. S11 Pt 4f XPS spectra of (A) freshly prepared and (B) spent 0.1Pt$_1$/ZrO$_2$-flame in methane combustion at 700 °C.

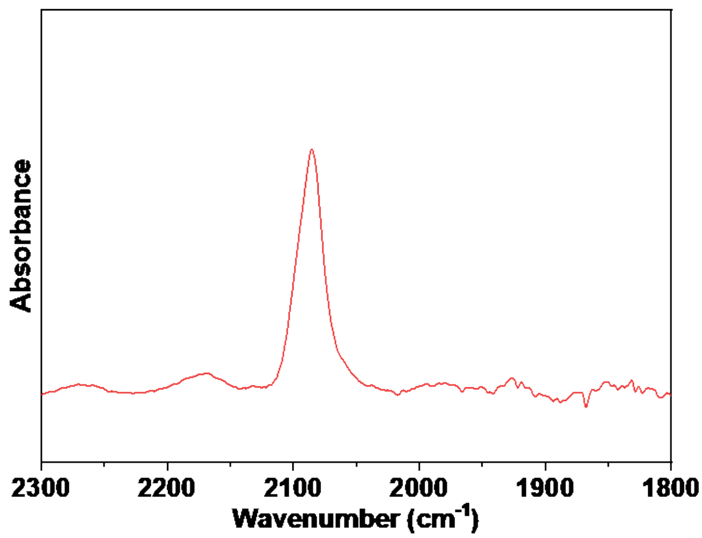

Fig. S12 CO adsorption on the 0.1Pt$_1$/ZrO$_2$-flame after long term stability test in methane combustion at 700 °C.

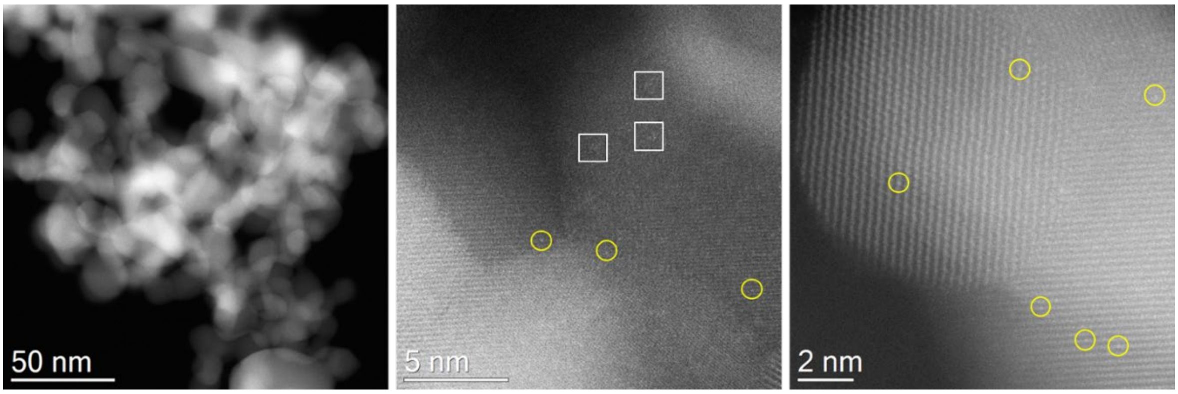

Fig. S13 Representative STEM-HAADF images of $0.1Pt_1/ZrO_2$-flame after long term stability test in methane combustion. Pt clusters are highlighted by white squares while single Pt atoms are highlighted with yellow circles.

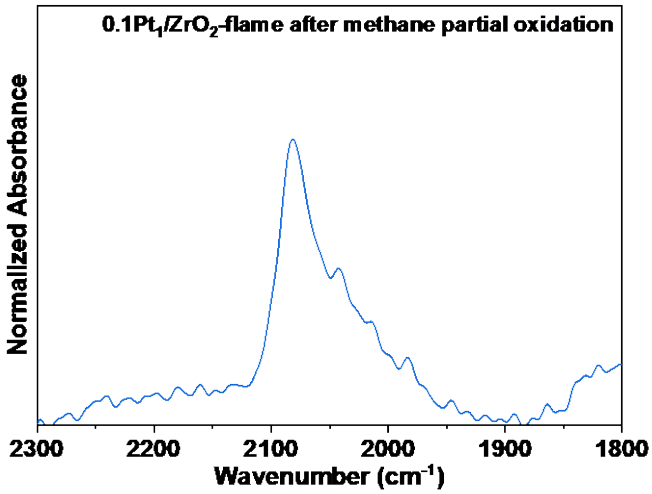

Fig. S14 CO adsorption on the $0.1Pt_1/ZrO_2$-flame after long term stability test in methane combustion at 700 ^oC