Supporting information

Acidic nanomaterials (TiO_2, ZrO_2, and Al_2O_3) are coke storage components that reduce deactivation of Pt-Sn/γ-Al_2O_3 catalyst in propane dehydrogenation

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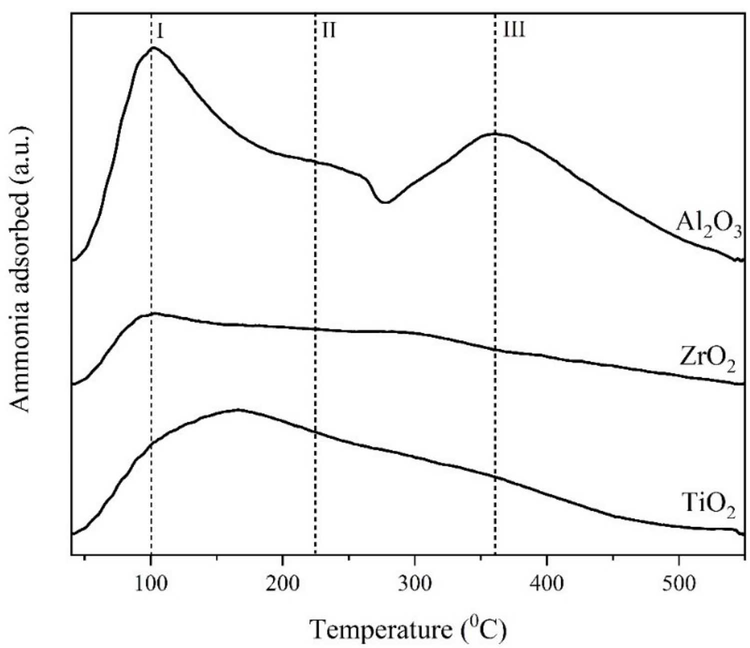

Fig. S1 NH_3-TPD profiles of acidic nanomaterials.

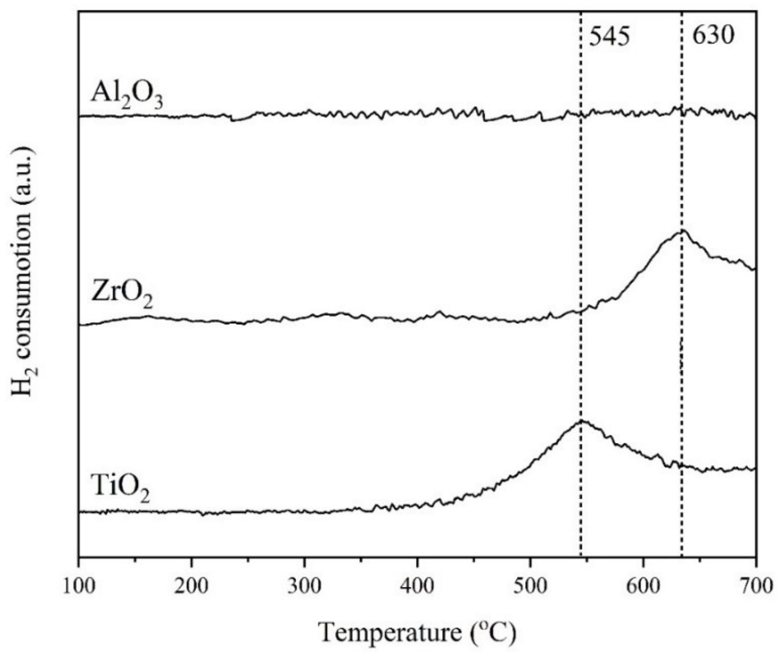

Fig. S2 H_2-TPR profiles of acidic nanomaterials.

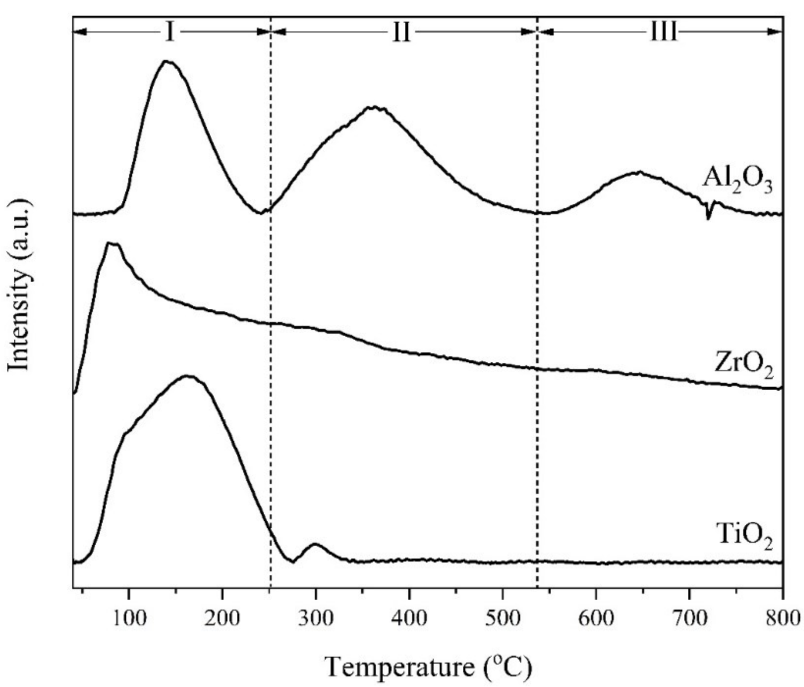

Fig. S3 O_2-TPD profiles of acidic nanomaterials.

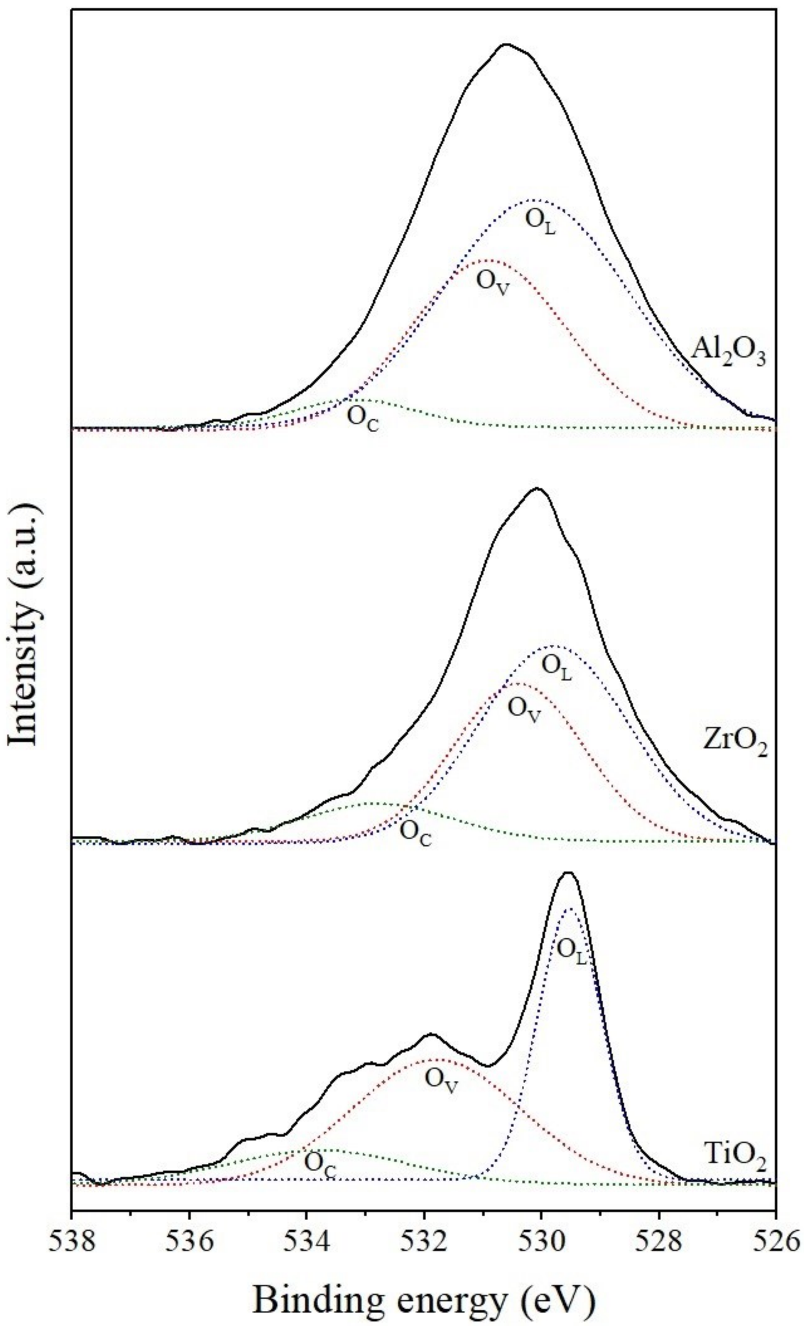

Fig. S4 O1 s peak in the XPS spectrum of acidic nanomaterials.

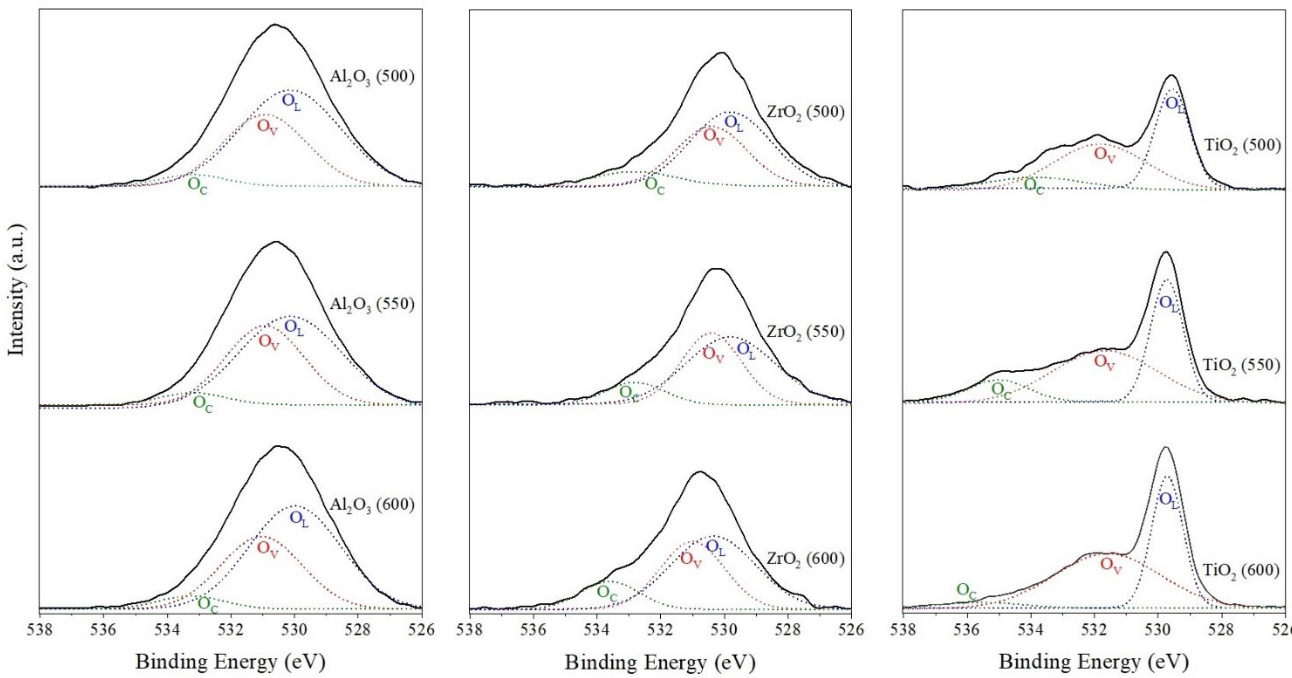

Fig. S5 O1 s peak in the XPS spectrum of acidic nanomaterials with different temperature of pretreatment.

Table S1 Summerized converison and products selectivity during propane dehydrogenation

Initial at 0 h

Catalysts	Conversion (%)	Selectivity (%)						
		C_1	C_2	$C_2^=$	$C_3^=$	C_4	$C_4^=$	C_5^+
inert	0.2	6.8	16.1	11.5	40.9	24.8	0.0	0.0
Al_2O_3	0.8	23.1	0.8	35.5	38.5	0.0	2.1	0.0
ZrO_2	1.0	13.9	0.4	16.1	69.7	0.0	0.0	0.0
TiO_2	7.2	2.4	1.2	2.2	93.7	0.1	0.5	0.0
Pt-Sn/γ-Al_2O_3 + inert	26.2	3.4	4.8	0.4	82.9	3.0	4.5	1.0
Pt-Sn/γ-Al_2O_3 + Al_2O_3	27.7	4.3	5.6	0.4	80.5	3.5	4.9	1.0
Pt-Sn/γ-Al_2O_3 + ZrO_2	30.3	7.0	8.2	0.5	77.8	2.6	3.2	0.7
Pt-Sn/γ-Al_2O_3 + TiO_2	27.7	6.0	7.1	0.4	75.8	3.0	3.5	4.2

Final at 5.1 h

Catalysts	Conversion (%)	Selectivity (%)						
		C_1	C_2	$C_2^=$	$C_3^=$	C_4	$C_4^=$	C_5^+
inert	0.3	8.8	10.8	16.4	48.0	16.1	0.0	0.0
Al_2O_3	1.1	17.7	0.7	28.8	51.8	0.0	1.0	0.0
ZrO_2	2.7	5.5	0.5	7.2	86.9	0.0	0.0	0.0
TiO_2	2.3	5.5	1.2	8.6	84.7	0.0	0.0	0.0
Pt-Sn/γ-Al_2O_3 + inert	12.2	2.7	1.9	2.0	89.4	0.2	2.7	1.2
Pt-Sn/γ-Al_2O_3 + Al_2O_3	12.5	3.2	1.9	2.3	90.2	0.1	2.0	0.3
Pt-Sn/γ-Al_2O_3 + ZrO_2	24.1	1.8	2.1	0.5	91.8	0.5	2.0	1.3
Pt-Sn/γ-Al_2O_3 + TiO_2	19.3	2.1	2.1	0.1	90.6	0.3	2.6	1.3

Table S2 Textural properties of acidic nanomaterials

Nanomaterials	BET surface area ($m^2 . g^{-1}$)	Pore size (nm)	Pore volume ($cm^3 . g^{-1}$)
Al_2O_3	123.5	12.7	0.54
ZrO_2	27.1	18.9	0.14
TiO_2	37.3	26.0	0.30

Table S3 Amount of acidity of nanomaterials

Nanomaterials	Amount of acidity (μmol NH_3. g cat^{-1})			
	Weak	Medium	Strong	Total
Al_2O_3	864	1152	1283	3298
ZrO_2	130	181	834	1149
TiO_2	175	1099	916	2191

Table S4 CO-chemisorption of the Pt-Sn/γ-Al_2O_3 catalyst with acidic nanomaterials

Catalysts	Amount of CO adsorbed (μmol CO. g cat^{-1})	Pt dispersion (%)
Pt-Sn/γ-Al_2O_3 + inert	12.3	80.0
Pt-Sn/γ-Al_2O_3 + Al_2O_3	13.2	85.8
Pt-Sn/γ-Al_2O_3 + ZrO_2	14.2	92.3
Pt-Sn/γ-Al_2O_3 + TiO_2	15.0	97.5

Table S5 O_2-TPD results of acidic nanomaterials

Nanomaterials	O_2-TPD peaks position (°C)	O_2 desorption (mmol O_2. g cat^{-1})
Al_2O_3	146	0.44 (O_v)
	368	0.48
	654	0.13
ZrO_2	87	0.56 (O_v)
	267	0.43
	529	0.30
TiO_2	165	0.93 (O_v)
	307	0.02

Table S6 XPS results of acidic nanomaterials

Nanomaterials	O_V/O_L
Al_2O_3	0.63
ZrO_2	0.69
TiO_2	1.23

Table S7 Adsorption energy of propylene and propadiene on acidic nanomaterials by *in-situ* DSC

Nanomaterials	Propylene ($J. g cat^{-1}$)	Propadiene ($J. g cat^{-1}$)
Al_2O_3	1.03	5.07
ZrO_2	1.27	5.33
TiO_2	1.46	6.50

Table S8 The summarized coke forms during the in *situ* DRIFT study of propadiene at different temperature

Nanomaterials	Temp. (^oC)	Area of coke forms			Differentiation [a]		
		C=C	Aliphatics	Aromatics	C=C	Aliphatics	Aromatics
TiO_2	40	1.22	0.036	0.01	1.00	0.00	0.00
	100	1.02	0.048	0.03	0.84	1.33	3.00
	200	0.32	0.02	0.31	0.26	0.56	31.00
	300	0.07	0.011	4.67	0.06	0.31	467.00
ZrO_2	40	3.49	0.12	0.08	1.00	0.00	0.00
	100	3.47	0.17	0.11	0.99	1.42	1.38
	200	0.76	0.16	1.56	0.22	1.33	19.50
	300	0.05	0.08	8.5	0.01	0.67	106.25
Al_2O_3	40	3.51	0.009	1.47	1.00	0.00	0.00
	100	1.97	0.016	2.27	0.56	1.78	1.54
	200	1.73	0.062	2.43	0.49	6.89	1.65
	300	1.46	0.152	1.81	0.42	16.89	1.23

[a] At 40 ^oC, there is no differentiation (initial = 1.00).
At elevated temperature, differentiation = area $_{i \text{ at that temperature}}$ / area $_{i \text{ at } 40\ ^oC}$

Table S9 The summarized coke deposition and oxygen vacancies of different pretreated acidic nanomaterials

Nanomaterials	O_V/O_L	Coke deposition on nanomaterials (%)
Al_2O_3 500 ^oC	0.63	N/A
Al_2O_3 550 ^oC	0.64	N/A
Al_2O_3 600 ^oC	0.64	N/A
ZrO_2 500 ^oC	0.69	2.5
ZrO_2 550 ^oC	0.71	2.5
ZrO_2 600 ^oC	0.70	2.5
TiO_2 500 ^oC	1.23	3.1
TiO_2 550 ^oC	1.39	3.5
TiO_2 600 ^oC	1.41	3.7