Supporting Information

Catalysis Science & Technology

Siliceous tin phosphates as effective bifunctional catalysts for selective conversion of dihydroxyacetone to lactic acid

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Table of Contents

Tables:

Table S1. Physicochemical properties of the calcined siliceous tin phosphates.

Table S2. Conversion of DHA and product yields over different calcined tin phosphates in water.

Table S3. Conversion of DHA and product yields over different tin phosphates in water.

Table S4. Characterization of recycled as-synthesized Si_6-Sn(IV)P and Sn(IV)P catalyst by adsorption, ICP, and TGA analysis.

Figures:

Fig. S1. HPLC chromatogram of the aqueous phase obtained from the hydrothermal treatment of GLA (conditions: 0.3125 M GLA, 80 mg Si_6-Sn(IV)P, 140 °C, 15 min).

Fig. S2. Wide-angle XRD profile of the Si_6-Sn(IV)P catalyst.

Fig. S3. TEM images of the as-synthesized (left) and calcined (right) Si_6-Sn(IV)P.

Fig. S4. UV-vis DRS spectra of the as-synthesized and calcined Si_6-Sn(IV)P. The recycled line is the spectrum of the as-synthesized sample after the 3rd reuse.

Fig. S5. NH_3-TPD curves of Si_6-Sn(IV)P. The signals are scaled to weight.

Fig. S6. Deconvoluted XPS spectra of O 1s for as-synthesized (a) and calcined (b) Si_6-Sn(IV)P samples.

Fig. S7. The results of DHA conversion after 5 h (Conditions: 0.3125 M DHA, 80 mg Catalyst, 140 °C, 6 h). Sn-Beta and Sn(IV)P were used as references.

Fig. S8. TGA analysis of uncalcined silica modified tin phosphates with varying TEOS amounts.

Table S1 Physicochemical properties of the calcined siliceous tin phosphates.

Entry	Catalyst	Sn source	Specific surface area ($m^2\ g^{-1}$)	Sn content[a] wt%	Si content[a] wt%	Total acid sites[b] (mmol g^{-1})
1	Sn(IV)P	$SnCl_4{\cdot}5H_2O$	168	47.2	-	0.67
2	Si_6-Sn(IV)P-o	SnO_2	171	60.8	9.3	0.17
3	Si_6-Sn(II)P	$SnCl_2{\cdot}2H_2O$	135	22.3	11.4	0.11
4	Si_2-Sn(IV)P	$SnCl_4{\cdot}5H_2O$	176	44.5	5.1	0.55
5	Si_4-Sn(IV)P	$SnCl_4{\cdot}5H_2O$	208	39.2	10.2	0.51
6	Si_6-Sn(IV)P	$SnCl_4{\cdot}5H_2O$	192	34.6	13.2	0.46
7	Si_8-Sn(IV)P	$SnCl_4{\cdot}5H_2O$	157	31.7	16.5	0.41
8	Si_{10}-Sn(IV)P	$SnCl_4{\cdot}5H_2O$	173	28.4	18.8	0.35
9	Si_6-Sn(IV)P-g[c]	$SnCl_4{\cdot}5H_2O$	139	30.1	14.6	0.42

[a] Dtermined by ICP analysis, [b] Determined by ammonia TPD, [c] The silicon source is silica gel.

Table S2. Conversion of DHA and product yields over different calcined tin phosphates in water.[a]

Entry	Catalyst	Conv. (%)	PA (%)	LA (%)
1	Si_2-Sn(IV)P	45.7	39.7	5.9
2	Si_4-Sn(IV)P	39.1	31.4	4.3
3	Si_6-Sn(IV)P	36.4	30.6	3.4
4	Si_8-Sn(IV)P	30.6	25.8	2.5
5	Si_{10}-Sn(IV)P	26.3	20.5	3.4

[a] *Reaction conditions*: 0.3125 M DHA, 80 mg Catalysts, 140 °C, 15 min.

Table S3. Conversion of DHA and product yields over as-synthesized tin phosphates in water[a]

Entry	Catalyst	Conv. (%)	PA (%)	LA (%)
1	Blank	1.01	<0.5	<0.5
2	H_3PO_4	23.1	18.6	0.8
3	$SnCl_4 \cdot 5H_2O$	28.3	20.7	4.1
4	$SnCl_2 \cdot 2H_2O$	27.3	23.6	5.4
5	Si_6-Sn(IV)P-o	3.3	1.8	<0.5
6	Si_6-Sn(II)P	2.5	1.4	<0.5
7	Si_2-Sn(IV)P	70.8	59.2	9.4
8	Si_4-Sn(IV)P	72.7	58.3	12.5
9	Si_6-Sn(IV)P	72.8	58.6	12.6
10	Si_8-Sn(IV)P	75.9	56.7	11.2
11	Si_{10}-Sn(IV)P	57.4	45.0	10.1
12	Sn-Beta	27.5	5.1	14.3

[a] *Reaction conditions*: 0.3125 M DHA, 80 mg Catalysts, 140 °C, 15 min.

Table S4. Characterization of recycled as-synthesized Si_6-Sn(IV)P and Sn(IV)P catalyst by adsorption, ICP, and TGA analysis.

Catalyst	Run	Specific surface area ($m^2\ g^{-1}$)	Total acid sites (mmol g^{-1})	Relative Sn content (%)	Relative P content (%)	Weight loss (%)	Carbon deposition (%)
Si_6-Sn(IV)P	Fresh	137	0.77	100	100	9.1	-
	1	135	0.73	96.3	94.6	9.35	0.25
	2	141	0.65	95.7	93.1	9.41	0.31
	3	129	0.63	95.2	92.5	9.59	0.49
Sn(IV)P	Fresh	146	0.72	100	100	16.2	-
	1	140	0.65	94.5	93.7	16.91	0.71
	2	137	0.59	93.6	92.5	17.13	0.93
	3	131	0.53	92.2	92.0	17.45	1.25

Fig. S1.

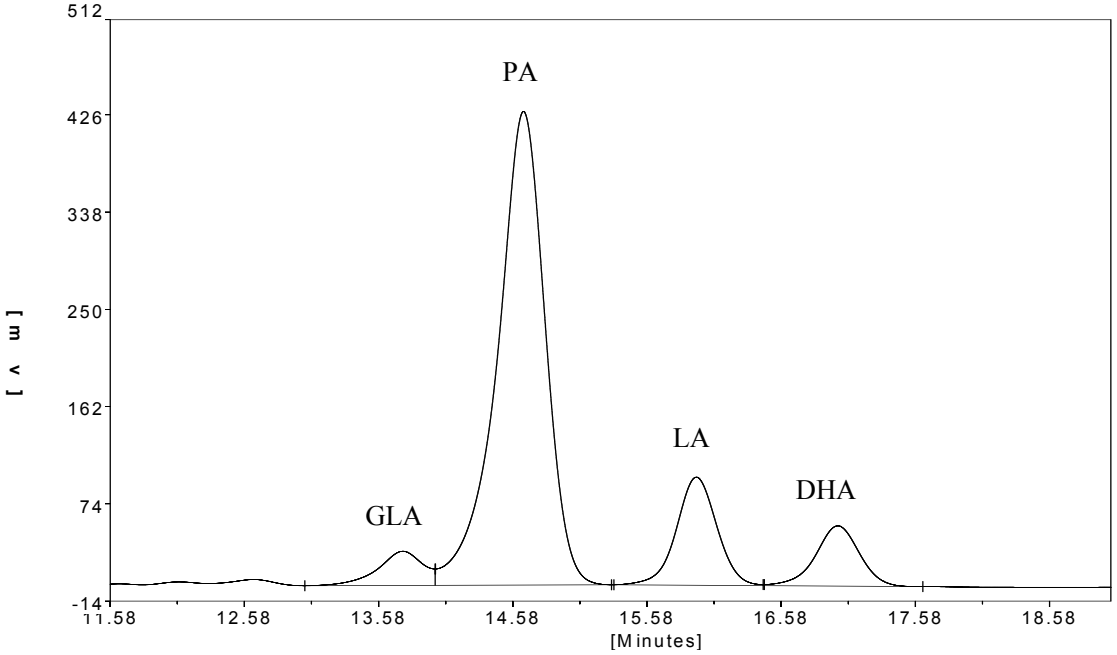

512
426
338
250
162
74
-14
[m v]
PA
LA
DHA
GLA
11.58
12.58
13.58
14.58
15.58
16.58
17.58
18.58
[Minutes]

Fig. S2.

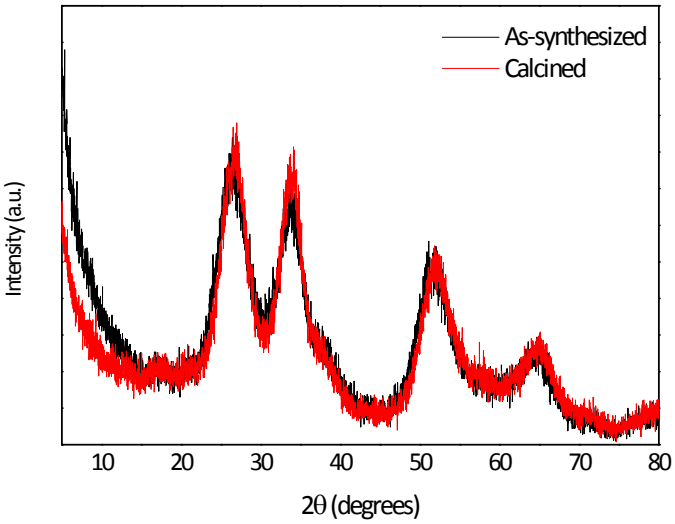

As-synthesized
Calcined
Intensity (a.u.)
10
20
30
40
50
60
70
80
2θ (degrees)

Fig. S3.

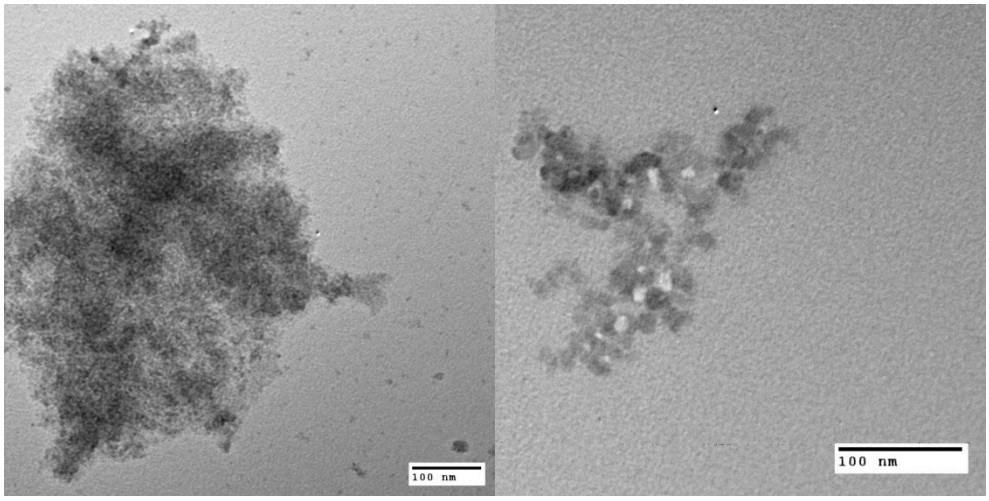


Fig. S4.

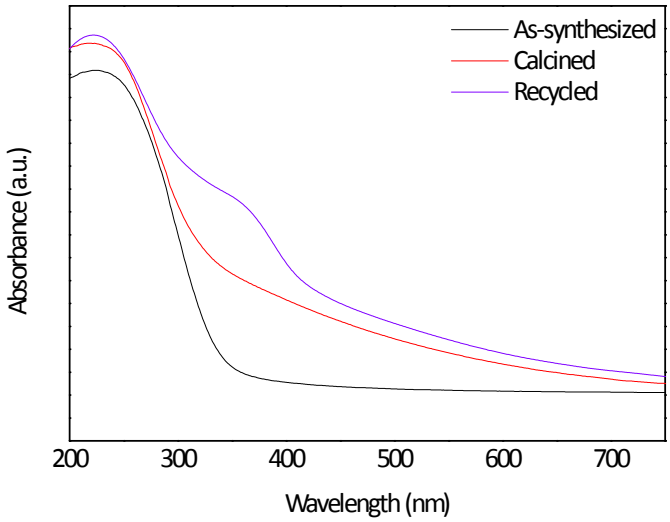

As-synthesized
Calcined
Recycled
Absorbance (a.u.)
200
300
400
500
600
700
Wavelength (nm)

Fig. S5.

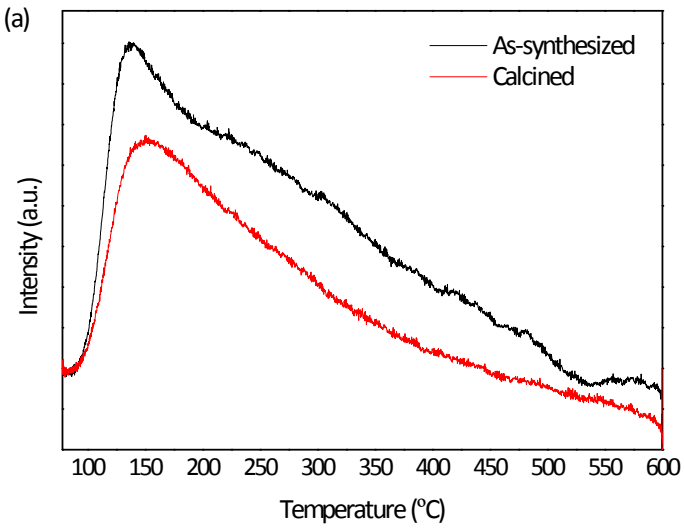

(a)
As-synthesized
Calcined
Intensity (a.u.)
100
150
200
250
300
350
400
450
500
550
600
Temperature (°C)

Fig. S6.

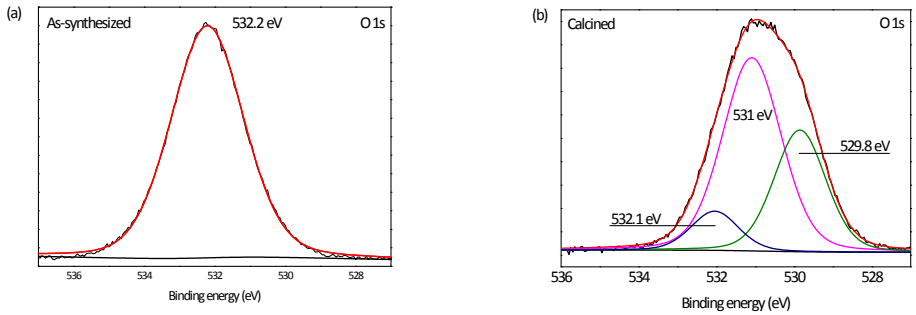

(a)
As-synthesized
532.2 eV
O 1s
536
534
532
530
528
Binding energy (eV)
(b)
Calcined
O 1s
531 eV
529.8 eV
532.1 eV
536
534
532
530
528
Binding energy (eV)

Fig. S7.

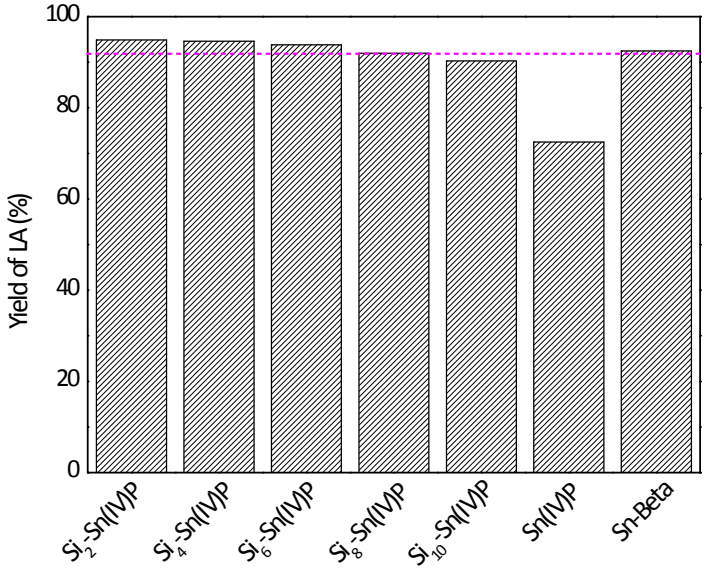
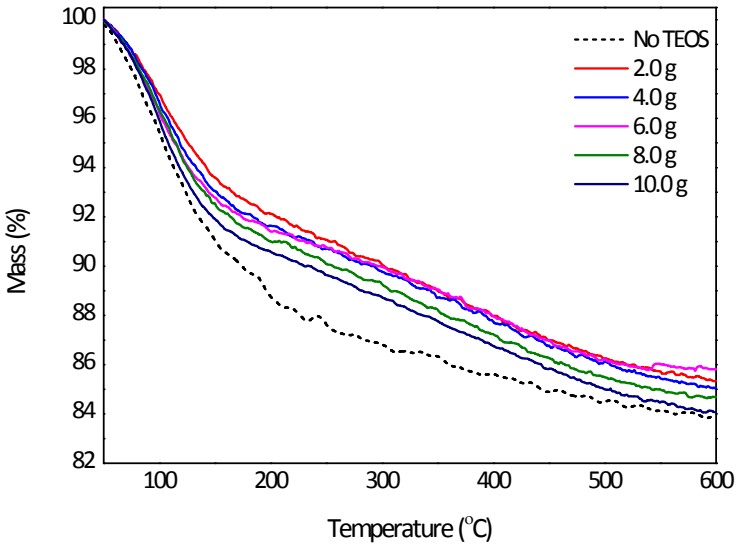

Yield of LA (%)
100
80
60
40
20
0
Si2-Sn(IV)P
Si4-Sn(IV)P
Si6-Sn(IV)P
Si8-Sn(IV)P
Si10-Sn(IV)P
Sn(IV)P
Sn-Beta

Fig. S8.


No TEOS
2.0 g
4.0 g
6.0 g
8.0 g
10.0 g
Mass (%)
Temperature (°C)
100
98
96
94
92
90
88
86
84
82
100
200
300
400
500
600