SUPPORTING INFORMATION

Synergetic effects of bimetal in modified Beta zeolite for lactic acid synthesis from biomass derived carbohydrates

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Figures S1-S7

Tables S1-S4

Supporting Figures

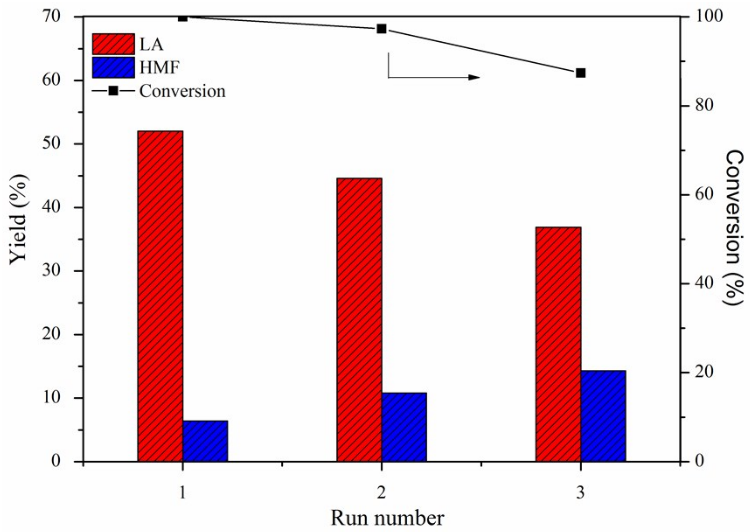

Fig.S1. Reuse of the Pb-Sn-Beta catalysts. Reaction conditions: 190°C, 2 h, Air, 225 mg glucose and 200 mg Pb-Sn-Beta (0.3 $mmol\cdot g^{-1}$ metal loading, Pb/ Sn ratio= 4/7). LA: lactic acid

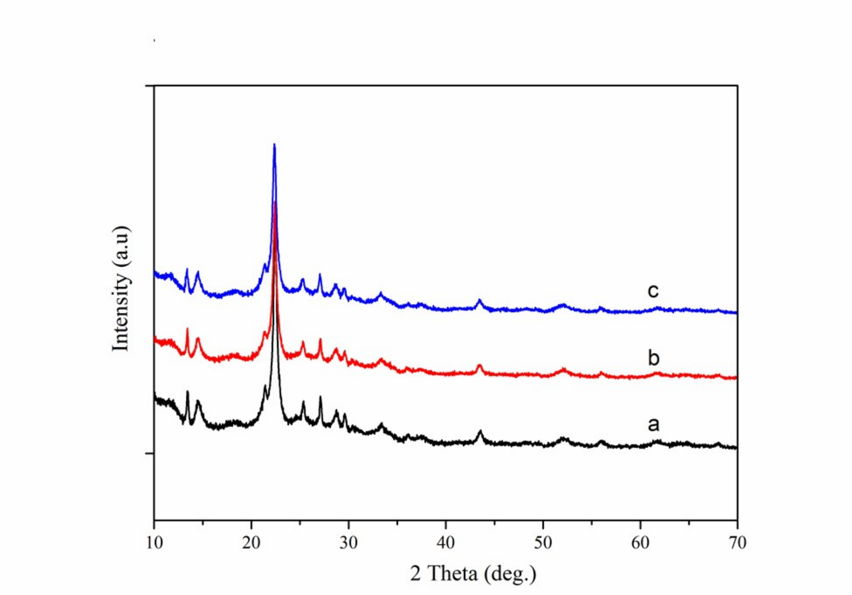

Fig.S2. X-ray diffraction patterns of reused catalysts. a. fresh catalyst; b. catalyst after first calcination; c. catalyst after second calcination

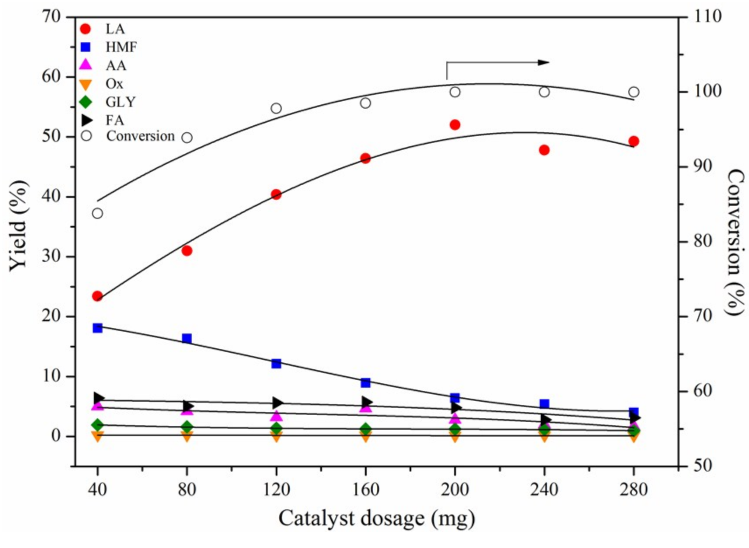

Fig.S3. Effect of catalyst dosage on the yields of main products with Pb-Sn-Beta. Reaction conditions: 190°C, 2 h, Air, 225 mg glucose, Pb-Sn-Beta (0.3 $mmol\cdot g^{-1}$ metal loading, Pb/ Sn ratio= 4/7). LA: lactic acid, AA: acetic acid, FA: formic acid, GLY: glycolic acid, Ox: oxalic acid.

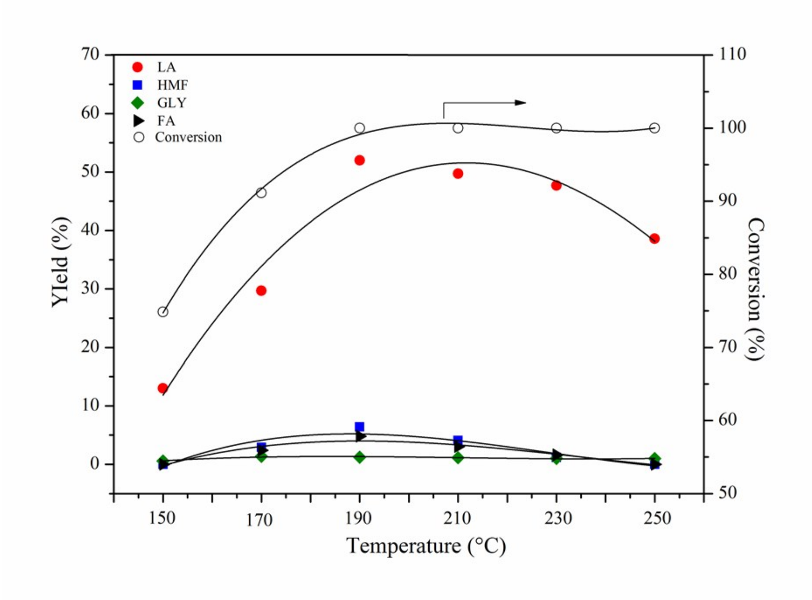

Fig.S4. Effect of temperature on the yields of main products with Pb-Sn-Beta. Reaction conditions: 2 h, Air, 225 mg glucose and 200 mg Pb-Sn-Beta (0.3 mmol·g^{-1} metal loading, Pb/ Sn ratio= 4/7). LA: lactic acid, AA: acetic acid, FA: formic acid, GLY: glycolic acid.

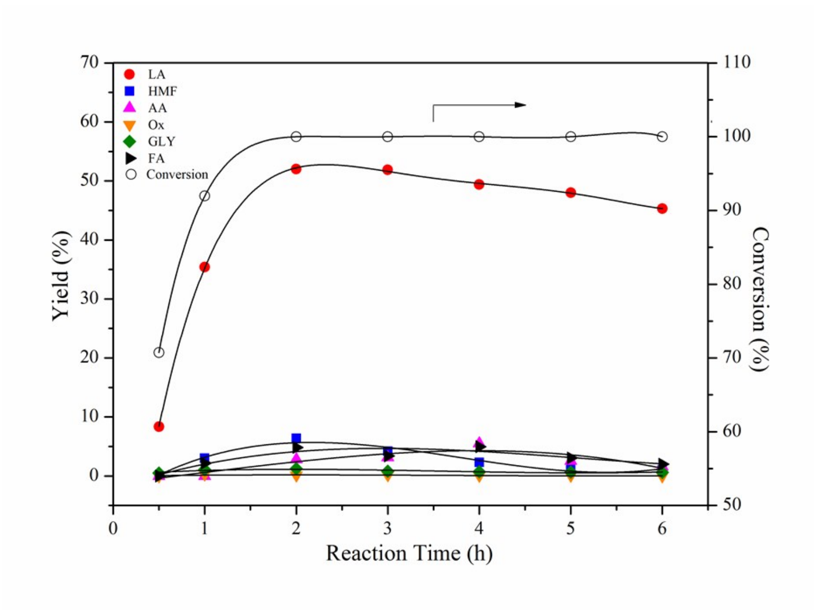

Fig.S5. Effect of reaction time on the yields of main products with Pb-Sn-Beta. Reaction conditions: 190°C, Air, 225 mg glucose and 200 mg Pb-Sn-Beta (0.3 mmol·g^{-1} metal loading, Pb/ Sn ratio= 4/7). LA: lactic acid, AA: acetic acid, FA: formic acid, GLY: glycolic acid, Ox: oxalic acid.

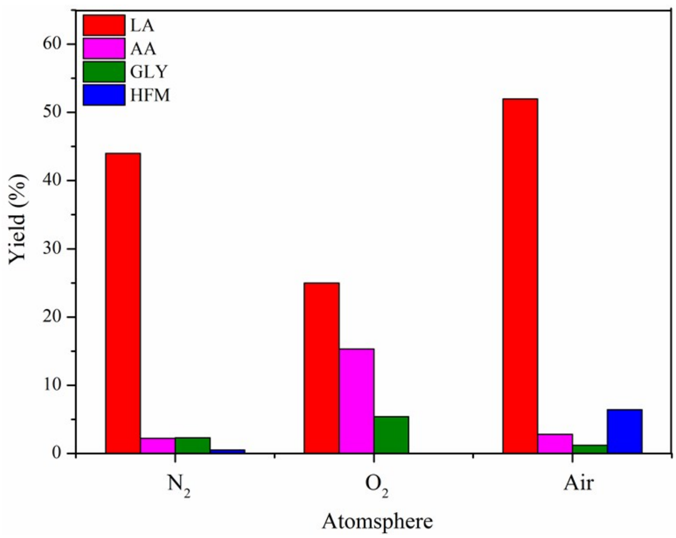

Fig.S6. Effect of atmosphere on the yields of main products with Pb-Sn-Beta. Reaction conditions: 190°C, 2 h, 225 mg glucose and 200 mg Pb-Sn-Beta (0.3 mmol·g^{-1} metal loading, Pb/ Sn ratio= 4/7). LA: lactic acid, AA: acetic acid, GLY: glycolic acid

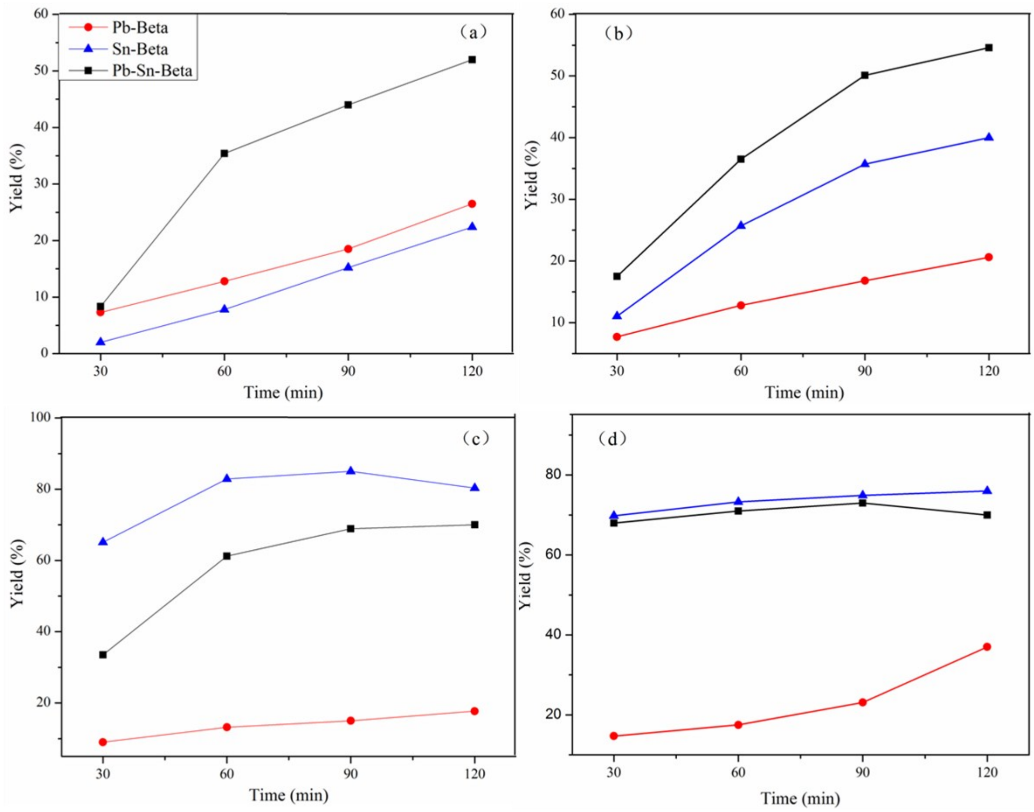

Fig.S7. Catalytic conversion of glucose and intermediates: (a) glucose; (b) fructose; (c) dihydroxyacetone; (d) pyruvaldehyde to lactic acid over Pb-Beta, Sn-Beta, and Pb-Sn-Beta zeolite respectively. Reaction conditions: 190°C, 2 h, Air, 10 ml water, 225 mg carbohydrate (7.5 mmol) and 200 mg catalyst (Pb-Sn-Beta: 0.3 mmol·g^{-1} metal loading, Pb/ Sn ratio= 4/7; Sn-Beta and Pb-Beta: 0.3 mmol·g^{-1} metal loading)

Supporting Tables

Table S1. Catalytic performance of different bimetal modified Beta zeolites

Entry	Catalyst[a]	Conversion (%)	The yields of aqueous-phase main products (%)				
			Lactic acid	HMF	GLY	FA	AA
1	Ni-Sn-Beta	>99	38.7	9.7	—	1.7	3.6
3	Cu-Sn-Beta	>99	28.0	14.7	7.0	2.8	2.3
4	Ce-Sn-Beta	>99	33.9	10.4	—	4.4	5.0
5	Pb-Sn-Beta	>99	45.1	5.3	1.6	5.0	6.2

[a] Metal loading is 0.3 mmol·g^{-1} and bimetallic ratio is 1:1. Reaction conditions: sugars (7.5 mmol C), 10 ml water, 200 mg catalyst, 190°C, 2 h, Air

Table S2. The contents of Lewis and Brønsted acid sites of different catalysts

Entry	Catalyst	B_{150}[a]	L_{150}[a]
		mmol·g^{-1}	
1	Beta	0.127	0.100
2	deAl-Beta	0.003	0.015
3	Pb-Sn-Beta-1	0.005	0.015
4	Pb-Sn-Beta-2	0.004	0.033
5	Pb-Sn-Beta-3	0.005	0.056
6	Pb-Sn-Beta-4	0.000	0.076
7	Pb-Sn-Beta-5	0.003	0.045
8	Sn-Beta	0.004	0.040
9	Pb-Beta	0.004	0.016
10	Pb-Sn-Beta[1thb]	0.003	0.020
11	Pb-Sn-Beta[2thc]	0.003	0.016

[a] Acidic properties of samples were determined by FT-IR spectra of adsorbed pyridine.[b] Catalyst after first calcination [c] Catalyst after second calcination

Table S3. The yield of lactic acid obtained from various carbohydrates over Pb-Sn-Beta zeolite

Entry	Substrate	Conversion (%)	Lactic acid yield (%)
1	Glucose	>99	52.0
3	Fructose	>99	54.6
4	Mannose	>99	53.8

5	Sucrose	>99	51.2
6	Lactose	>99	37.8
7	Cellulose	~30	10.1
8	Starch	~35	16.2

Reaction conditions: carbohydrate (7.5 mmol C), 10 ml water, 200 mg Pb-Sn-Beta (0.3 mmol·g^{-1} metal loading, Pb/ Sn ratio= 4/7), 190°C, 2 h, Air

Table S4. The ICP-OES analysis results of different Pb/Sn ratios

Pb/Sn ratio[a]	Pb (mmol·g^{-1})	Sn (mmol·g^{-1})
0/10	—	0.30
3/7	0.09	0.21
4/6	0.11	0.18
5/5	0.13	0.15
6/4	0.17	0.13
7/3	0.19	0.09
10/0	0.28	—

[a] The metal content of different Pb/Sn ratio catalysts is 0.3mmol·g^{-1} in Beta zeolites.