

Supplementary Information

**Direct conversion of glyceric acid to succinic acid by reductive  
carbonylation**

Linfeng Zhang ‡<sup>a</sup>, Changpo Ma ‡<sup>a</sup>, Chenyu Wang <sup>c</sup>, Guangyu Sun <sup>a</sup>, Yongqi Shu <sup>b</sup>,  
Wenya Zou <sup>b</sup>, Tao Yang <sup>a</sup>, Weiran Yang <sup>\*a</sup>

<sup>a</sup>School of Chemistry and Chemical Engineering, Nanchang University, No. 999 Xuefu Avenue, Jiangxi 330031, PR China.

<sup>b</sup>School of Resources & Environment, Nanchang University, No. 999 Xuefu Avenue, Jiangxi 330031, PR China.

<sup>c</sup>School of Future Technology, Nanchang University, No. 999 Xuefu Avenue, Jiangxi 330031, PR China.

‡: Linfeng Zhang and Changpo Ma contributed equally to this work.

Corresponding Author:

Name: Weiran Yang

E-mail: wyang16@ncu.edu.cn

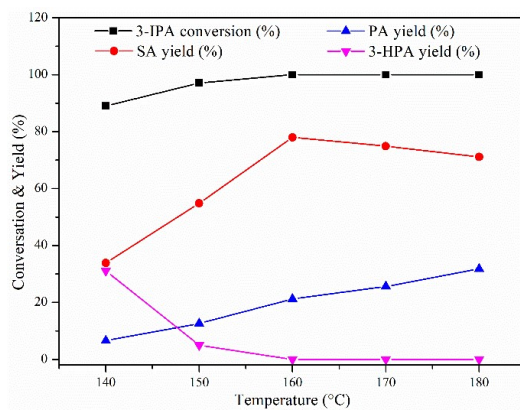


Fig. S1 Effect of temperature on the conversion of 3-IPA to SA. Reaction conditions: 3-IPA 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04 mmol, acetic acid 4 mL,  $\text{H}_2\text{O}$  1 mL, DPPB 0.06 mmol, CO 1 MPa, 500 rpm, 3 h.

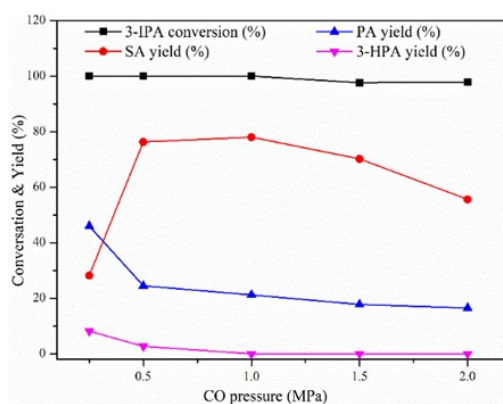


Fig. S2 Effect of CO pressure on the conversion of 3-IPA to SA. Reaction conditions: 3-IPA 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04 mmol, acetic acid 4 mL,  $\text{H}_2\text{O}$  1 mL, DPPB 0.06 mmol, 160 °C, 3 h, 500 rpm.

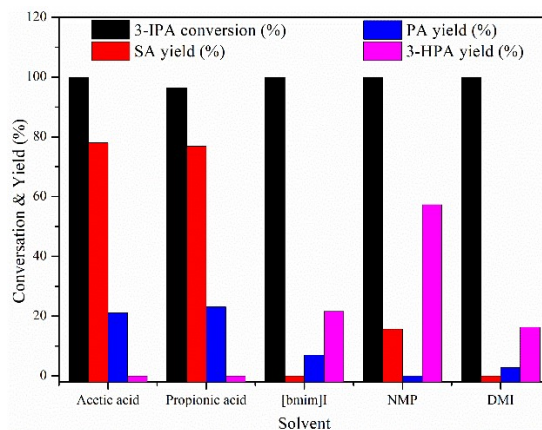


Fig. S3 Effect of solvents on the conversion of 3-IPA to SA. Reaction conditions: 3-IPA 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04 mmol, solvent 4 mL,  $\text{H}_2\text{O}$  1 mL, DPPB 0.06 mmol, 160 °C, 3 h, CO 1 MPa, 500 rpm.

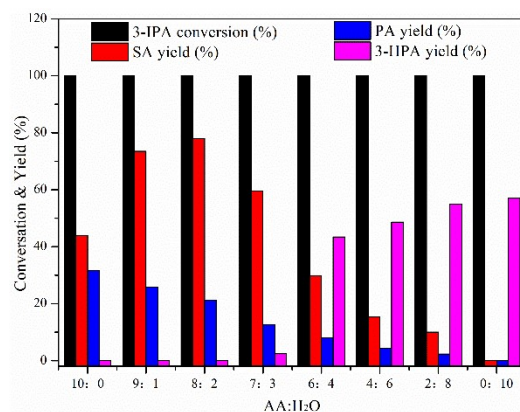


Fig. S4 Effect of the ratio of acetic acid to H<sub>2</sub>O on the conversion of 3-IPA to SA. Reaction conditions: 3-IPA 1 mmol, RhCl<sub>3</sub>·3H<sub>2</sub>O 0.04 mmol, acetic acid +H<sub>2</sub>O 5 mL, DPPB 0.06 mmol, 160 °C, 3 h, CO 1 MPa, 500 rpm.

Table S1 Study on the synthesis propionic acid from acetic acid

Entry	AA (mL)	H <sub>2</sub> O (mL)	I <sub>2</sub> (mmol)	T (°C)	t (h)	Propanoic acid yield (mmol)
1	3	2	0.6	160	8	0.030
2	5	0	0.6	160	8	0.041
3	3	2	0.6	160	12	0.026
4	3	2	1.2	160	8	0.031
5	3	2	0.6	180	8	0.042
6 <sup>a</sup>	3	2	0.6	160	8	0.027

Reaction conditions: RhCl<sub>3</sub>·3H<sub>2</sub>O 0.04 mmol, CO 1 MPa, H<sub>2</sub> 0.5 MPa. a: Substrate: 1mmol SA

Table S2 Effects of different ligands on the conversion of MG to SA

Entry	Ligand	Conv. (%)	Yield of SA (%)
1	DPPM	100	65.2
2	DPPP	100	49.7
3	DPPB	100	71.4
4	DPPE	100	70.1
5	DTBPF	100	68.3
6	1,1'-BIS(DICYCLOHEXYLPHOSPHINO)FERROCENE	100	59.6
7	DPPF	100	68.3
8	DCPP	100	67.2
9	R-binap	100	69.4
10	XantPhos	100	59.3
11	1,1,1-Tris(diphenylphosphinomethyl)ethane	100	51.8
12	tris(3-methoxyphenyl)phosphane	100	56.7

13	TPTP	100	61.2
14	PCy3	100	56.7
15	PPh3	100	62.4

Reaction conditions: MG 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04mmol,  $\text{I}_2$  0.6mmol, Ligand 0.06 mmol, AA 3 mL,  $\text{H}_2\text{O}$  2 mL, 160 °C, 8 h,  $\text{H}_2$  0.5 MPa, CO 1 MPa, 500 rpm.

Table S3 Effect of different acidic additives on the conversion of MG to SA

Entry	Acidic additive	Conv. (%)	Yield of SA (%)
1	TFA	100	66.5
2	MSA	100	70
3	TsOH	100	64.8

Reaction conditions: MG 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04mmol,  $\text{I}_2$  0.6mmol, DPPB 0.06 mmol, AA 3 mL,  $\text{H}_2\text{O}$  2 mL, 160 °C, 8 h,  $\text{H}_2$  0.5 MPa, CO 1 MPa, 500 rpm, acidic additive 0.5 mmol.

Table S4 Effect of different promoters on the conversion of MG to SA

Entry	Promoter	Conv. (%)	Yield of SA (%)
1	$\text{I}_2$	100	71.4
2	LiI	0	0
3	NaI	0	0
4	KI	0	0
5	$\text{MgI}_2$	0	0
6	$\text{ZnI}_2$	0	0
7	HCl	0	0
8	HI	100	67.6
9	$\text{CH}_3\text{I}$	100	27.3

Reaction conditions: MG 1 mmol,  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04 mmol, Promoter 0.6 mmol (calculated with I content of 1.2 mmol), DPPB 0.06 mmol, AA 3 mL,  $\text{H}_2\text{O}$  2 mL, 160 °C, 8 h,  $\text{H}_2$  0.5 MPa, CO 1 MPa, 500 rpm.

Table S5 The conversion of GA to SA

Entry	Substrate	Conv. (%)	Yield of SA (%)
1	GA	100	71.9

Reaction conditions: 0.53 g 20wt% GA aqueous solution (1 mmol GA),  $\text{RhCl}_3 \cdot 3\text{H}_2\text{O}$  0.04mmol,  $\text{I}_2$  0.6 mmol, DPPB 0.06 mmol, AA 3 mL,  $\text{H}_2\text{O}$  1.5 mL, 160 °C, 8 h,  $\text{H}_2$  0.5 MPa, CO 1 MPa, 500 rpm.

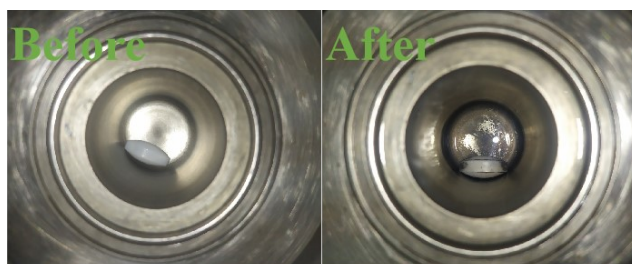


Fig. S5 Diagram of the corrosion-resistant liner before and after the reaction

### Parallel control experiments

And about the recycling experiment, a set of parallel control experiments were conducted, as shown in Table. S6. The “Detected SA yield” is the yield detected by the recycling experiment with glyceric acid as raw material. The “Lost SA yield” was obtained by SA yield loss in the parallel control experiments with succinic acid as substrate. The “Total SA yield” is the combination of the “Detected SA yield” and the “Lost SA yield”. In the Fresh experiment, the “Lost SA yield was not determined. The same method was used to calculate the yield of propionic acid.

Table. S6 Parallel control experiments

	Detected SA yield (%)	Lost SA yield (%)	Total SA yield (%)	Detected PA yield (%)	Lost PA yield (%)	Total PA yield (%)
Fresh	71.4	-	71.4	18.5	-	18.5
Recycle 1	70.8	0.6	71.4	18.5	0	18.5
Recycle 2	69.5	0.9	70.4	18.4	0.1	18.5
Recycle 3	68.7	1.1	69.8	18.9	2.7	21.6
Recycle 4	65.1	2.2	67.3	19.2	3.3	22.5