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Chemical Synthesis

Supplementary Materials

The transfer hydrogenation of levulinic acid to γ-valerolactone over CuNiAl catalyst

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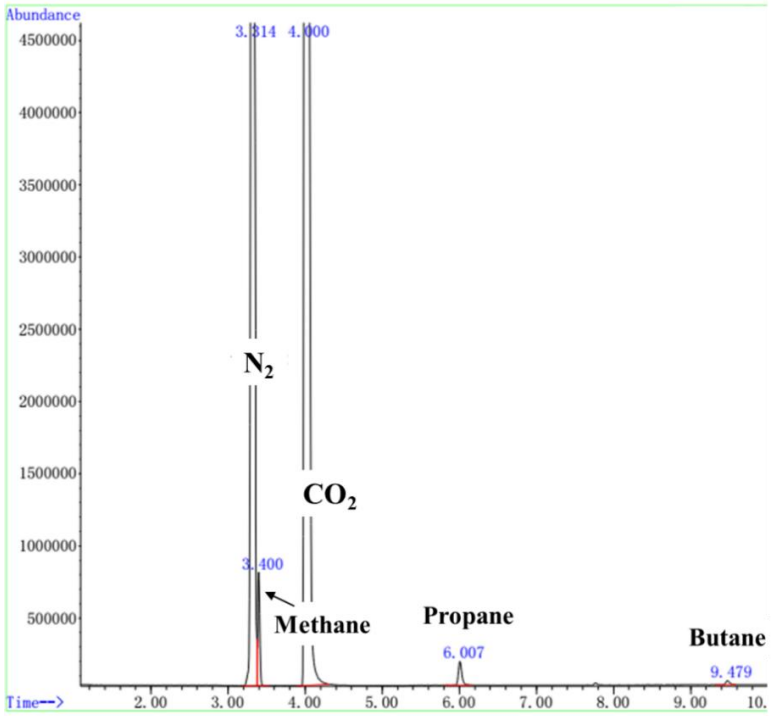
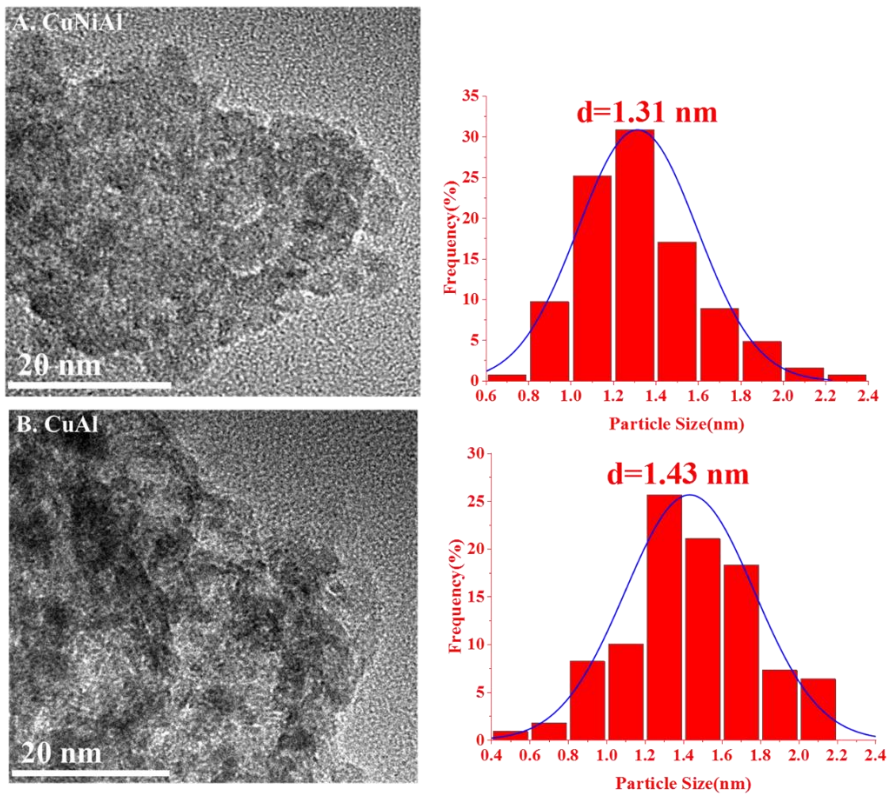
Supplementary Figures



Supplementary Figure 1. GC-MS analysis for gas products on CuNiAl catalyst.



Supplementary Figure 2. TEM images of (A) CuNiAl and (B) CuAl catalysts.

Supplementary Tables

Supplementary Table 1. The amount of total acid sites and basic sites of catalysts

Samples	Acidity (μmol·g^{-1})[a]	Basicity (mmol·g^{-1})[b]
CuAl	0.39	0.49
NiAl	0.50	0.54
CuNiAl	0.30	0.31

[a]The acidity was estimated by the amount of NH_3 desorption [Figure 5A]; [b]The basicity was estimated by the amount of CO_2 desorption [Figure 5B].

Supplementary Table 2. The surface ratio of $Cu^{2+}/Cu^{+/0}$ estimated from Cu 2p XPS spectra

Samples	$Cu^{2+}/Cu^{+/0}$
CuNiAl	0.35
CuAl	0.42
CuNiAl-used six runs	0.56
CuAl-used four runs	0.81

Supplementary Table 3. Comparison of the catalytic performances of non-noble metal catalysts in the transfer hydrogenation of LA to GVL with formic acid as hydrogen donor

Catalyst	Amount of catalyst (g)	LA (mmol)	FA/ LA	T (°C)	Time (h)	Conv. (%)	Sel. (%)	GVL forming rate (mmol·g_{catal}^{-1}·h^{-1})[a]	Ref.
Continuous fixed bed reaction									
20Ni60Cu/SiO_2	1	31.73	1	285	100	99	96	0.30	1
30Ni/SiO_2	1	97.60	5	250	10	99	92	8.88	2
30Ni/SiO_2	1	97.60	5	250	10	98	91.8	8.78	3
10Cu/Fe_2O_3	1	-	2	250	-	100	100	-	4
6Cu/SiO_2	0.5	43.50	3	250	10	56	87	4.24	5
HTC MgAl (3:1)	0.4	-	5	270	30	100	98	-	6
5Ni/CeO_2	0.2	20.51	3	275	14	72.6	90.1	4.79	7
MgO-UBE	0.5	-	2	270	-	100	100	-	8
Batch reaction									
20Cu/ZrO_2-OG	0.24	18	1	200	5	100	100	15	9
20Ni/ZrO_2	0.5	43	1	220	5	34.3	99	5.84	10
Raney-Ni	0.02	1	4	200	48	100	68.5	0.71	11
MnCo(20:1) oxide	0.2	1.5	10	230	20	78.9	76.7	0.23	12
ZnAl(2:1) oxide	1	41.5	5	140	6	87	100	6.02	13
16Cu42NiAl	0.05	5	2	210	6	100	97.3	16.17	This work

[a]The forming rate was calculated by the moles of GVL produced (mmol)/catalyst mass (g)/Reaction time (h).

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