The conversion of levulinic acid into γ-valerolactone using Cu-ZrO$_2$ catalysts

Daniel R. Jones,[a] Sarwat Iqbal,[a] Satoshi Ishikawa,[a,b] Christian Reece,[a] Liam Thomas, Peter J. Miedziak,[a] David J. Morgan,[a] Jennifer K. Edwards,[a] Jonathon K. Bartley,[a] David J. Willock,[a] Graham J. Hutchings [a],*

*hutch@cardiff.ac.uk

[a] Cardiff Catalysis Institute, Main Building, Park Place, Cardiff, CF24 3AT
[b] Catalysis Research Centre, Hokkaido University, N-21, W-10, Sapporo, 001-0021, Japan

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Table *S1*. Theoretical Cu/Zr molar ratios and the measured ratios determined by ICP-AES

Theoretical Cu/Zr Molar	Measured Cu/Zr
0.25	0.27
0.50	0.50
0.75	0.80
1.00	0.99
1.25	1.25
1.50	1.53
2.00	2.04

Table *S2*. BET surface area for the catalysts prepared with different Cu/Zr ratios

Theoretical Cu/Zr	BET surface area / $m^2\ g^{-1}$
0.25	23
0.50	18
0.75	32
1.00	149
1.25	90
1.50	86
2.00	81

Table *S3*. Particles sizes of catalysts prepared with different Cu/Zr ratio based on the most intense peak at 35° (hkl = (111)) using the Scherrer equation.

Cu/Zr ratio	CuO particle size / nm
0.25	Unable to acceptably estimate particle size using the Scherer equation
0.50	
0.75	
1.00	11.0
1.25	8.3
1.50	20.0

Table *S4*. BET surface areas and particles sizes of catalysts prepared with different calcination temperatures. Particle sizes based on the most intense peak at 35° (hkl = (111)) using the Scherrer equation.

Calcination temperature / °C	BET surface area / $m^2\,g^{-1}$	CuO particle size / nm
300	171	4.0
400	149	5.4
500	111	8.3
600	34	12.2
700	10	17.9
800	6	23.4

Table *S5*. BET surface areas and particles sizes of catalysts prepared with different precipitate ageing times. Particles sizes based on the most intense peak at 35° (hkl = (111)) using the Scherrer equation.

Precipitates ageing time / h	BET surface area / $m^2\,g^{-1}$	CuO particle size / nm
0	92.0	10.2
1	97.0	8.4
2	115	5.7
4	126	6.3
6	149	5.4
8	140	5.0
11	137	Unable to acceptably estimate particle size using the Scherer equation
16	121	
24	116	12.9

Table *S6*. Cu surface area determined by N_2O titration for Cu-ZrO$_2$ catalysts calcined at different temperatures.

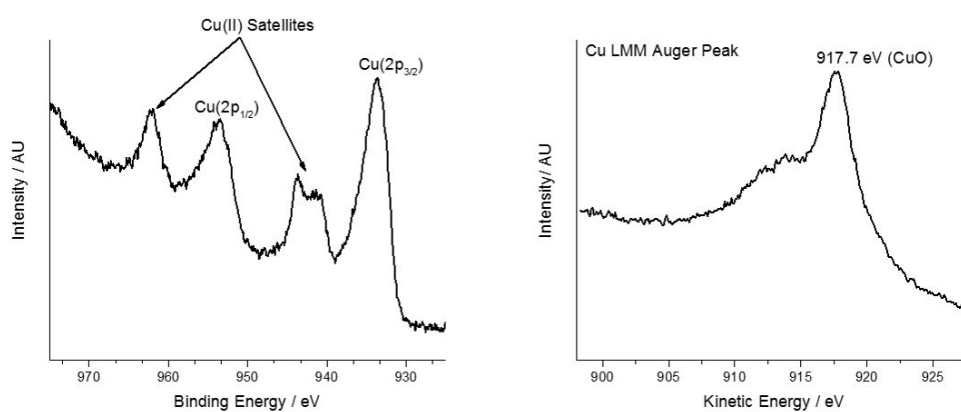| Calcination temperature / °C	Cu surface area / $m^2\,g^{-1}$
300	1.7
400	4.1
500	0.7
600	4.1
700	1.0

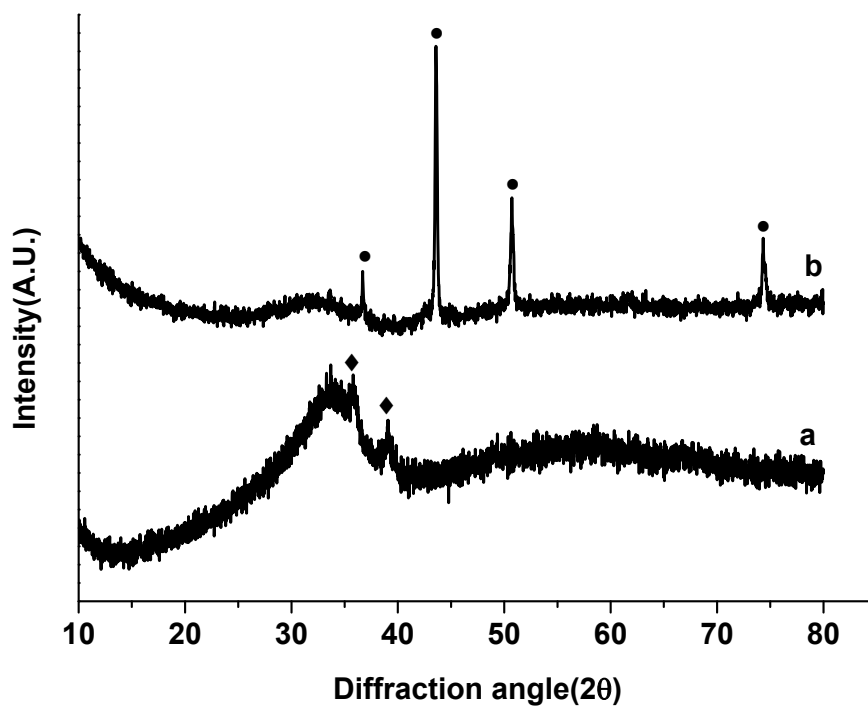**Figure *S1***. Typical XPS profile of CuO containing catalyst materials.

Figure *S2*. XRD patterns of the catalyst a) before and b) after reaction. ꙍ Cu, ☉CuO

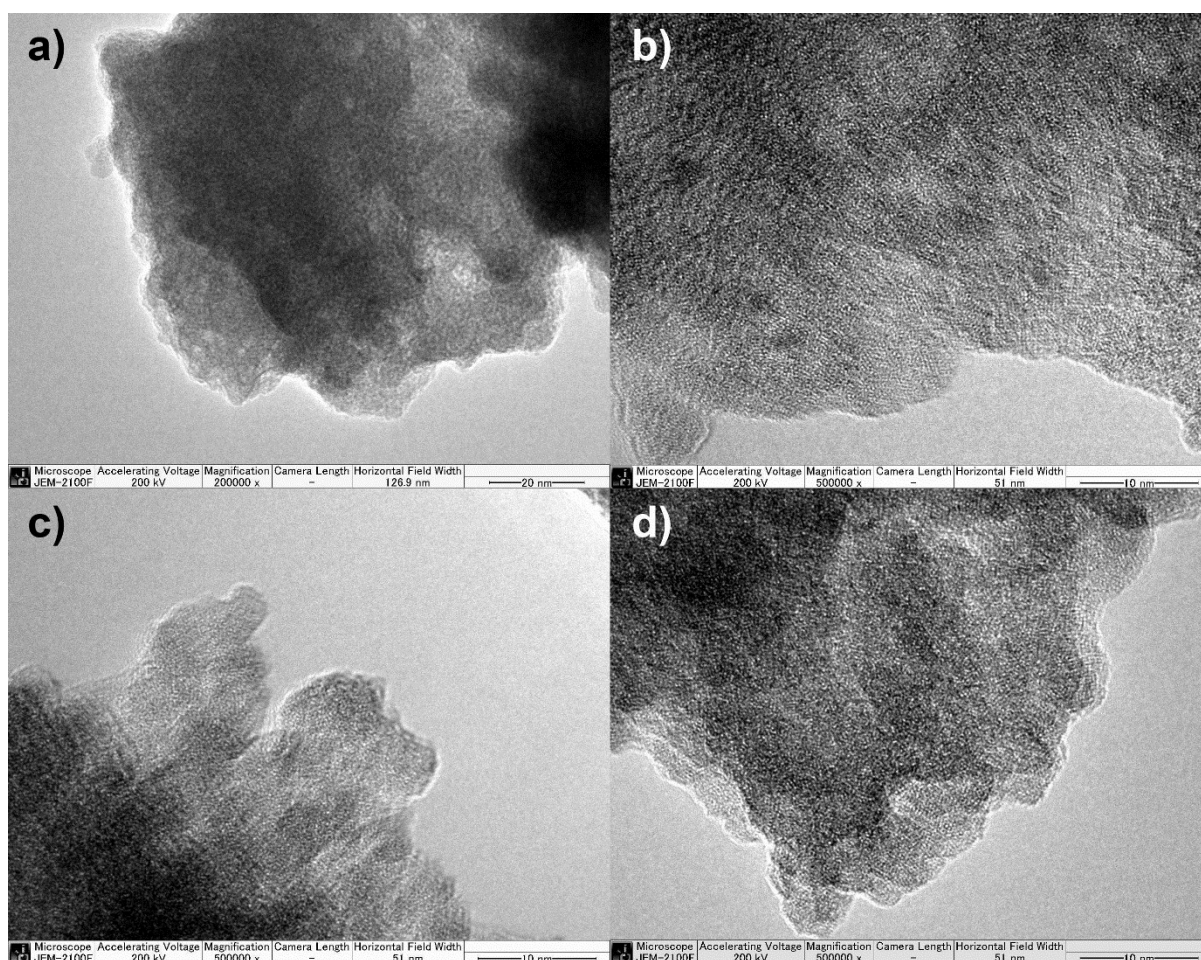Figure **S3**: Tem images of Cu/ZrO$_2$ a) unaged, b) after calcination for 4h, c) 6h and d) 24h.