Supplementary Information for:

Green Catalytic Process for γ-Valerolactone Production from Levulinic Acid and Formic Acid

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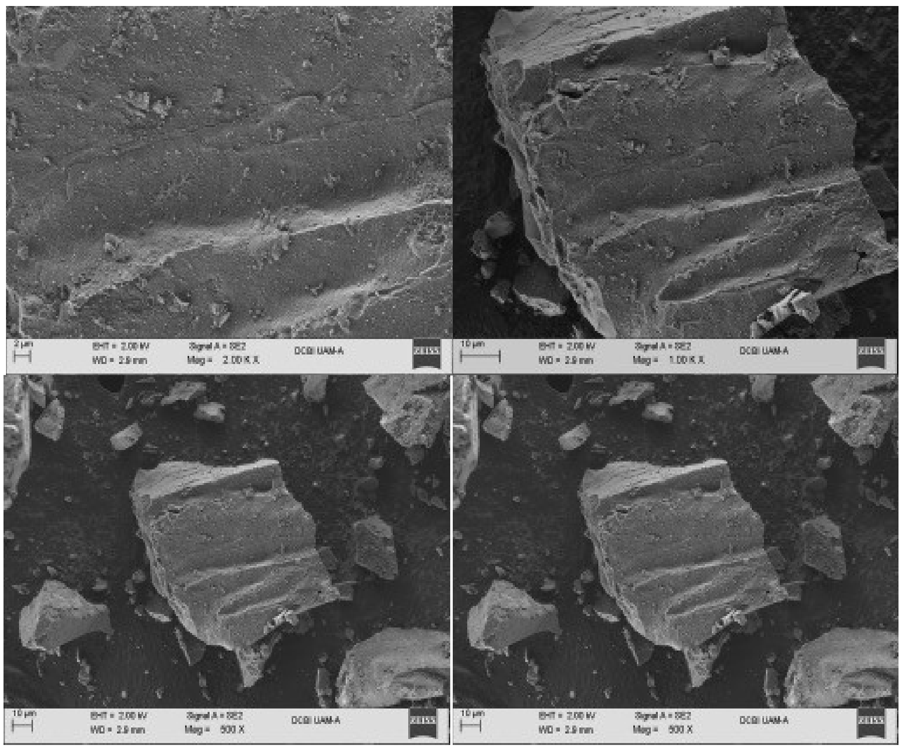
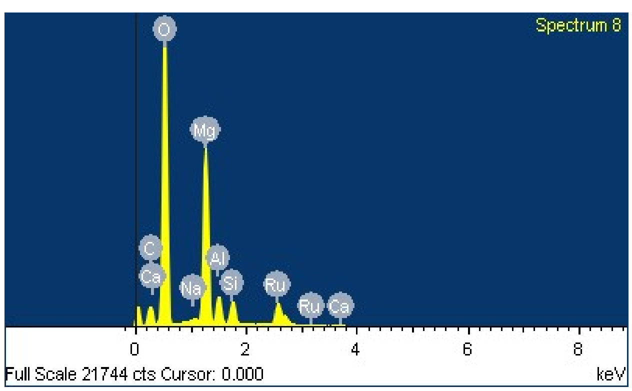
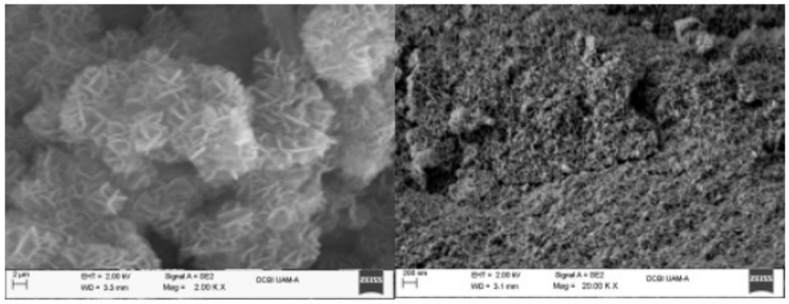
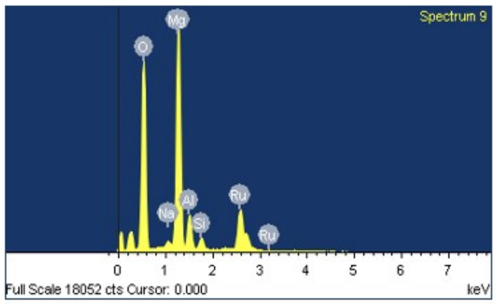




Element	Weight%	Atomic%
C K	5.11	8.37
O K	55.98	68.81
Na K	0.37	0.32
Mg K	18.79	15.20
Al K	3.26	2.38
Si K	3.19	2.24
Ca K	0.36	0.18
Ru L	12.92	2.51
Totals	100.00	

Figure SI1. SEM image and EDS pattern of HT-Ru





Element	Weight%	Atomic%
O K	44.90	65.28
Na K	0.60	0.60
Mg K	24.69	23.63
Al K	4.29	3.70
Si K	1.54	1.27
Ru L	23.99	5.52
Totals	100.00	

Figure SI2. SEM image and EDS pattern of MO-Ru

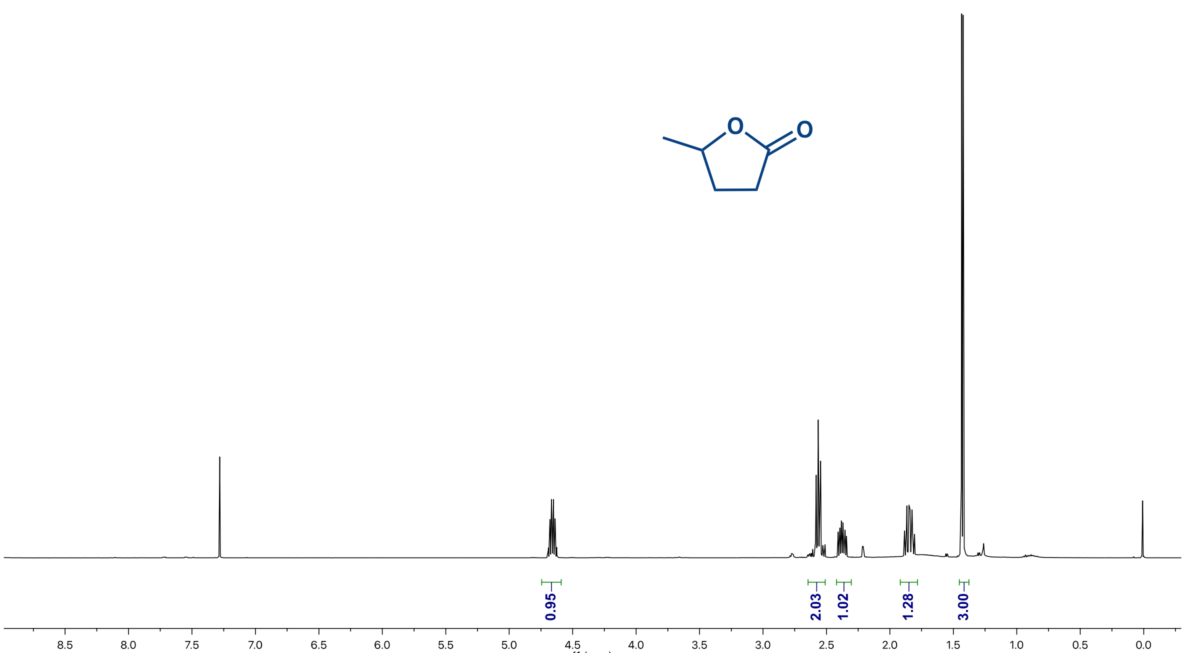


Figure SI3. ^{1}H NMR ($CDCl_3$) spectrum of crude reaction product from the hydrogenation of LA with FA catalyzed by MO-Ru under optimized reaction conditions (150°C, 1.5 h, [Ru] 0.5 mol%)

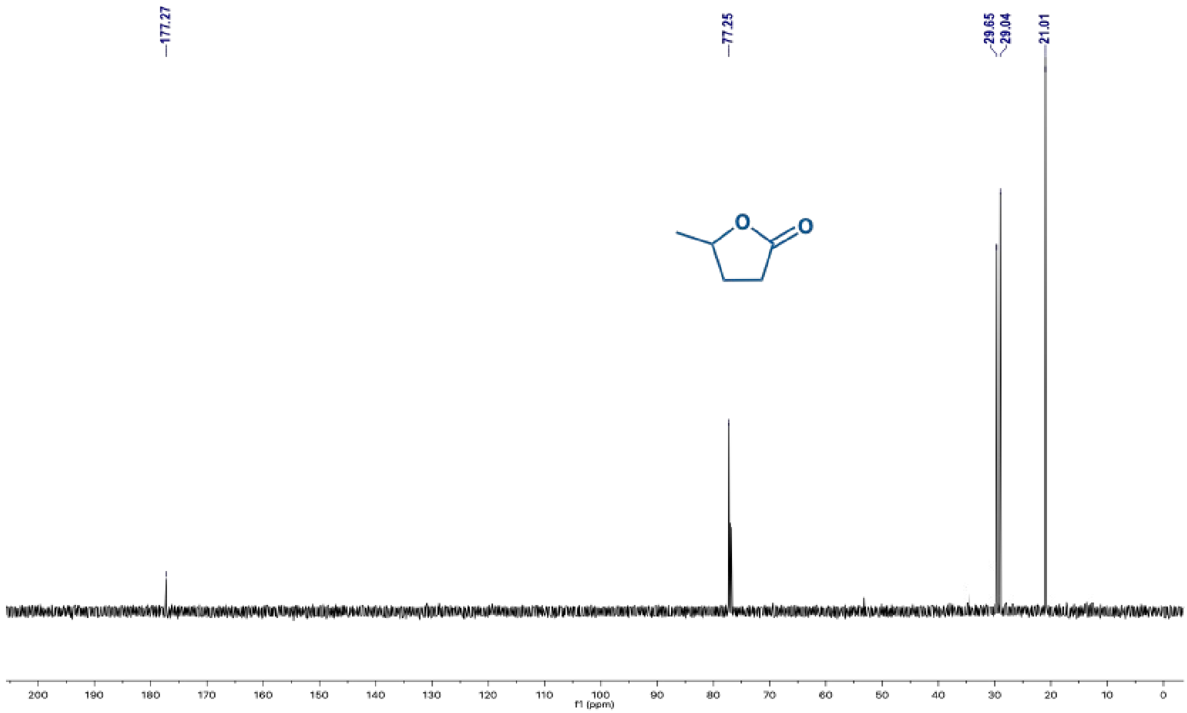


Figure SI4. ^{13}C NMR ($CDCl_3$) spectrum of crude reaction product from the hydrogenation of LA with FA catalyzed by MO-Ru under optimized reaction conditions (150°C, 1.5 h, [Ru] 0.5 mol%)

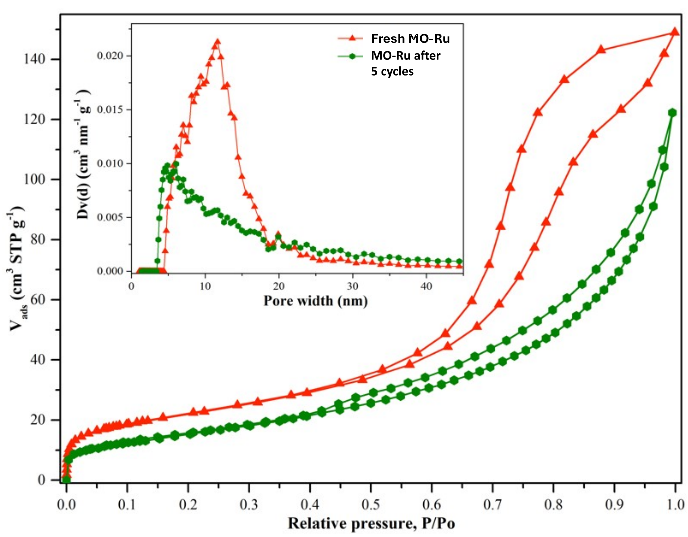


Figure SI5. Comparative Nitrogen isotherm at 77 K and PSD for Fresh MO-Ru and MO-Ru after 5 cycles.

Table S1. Textural properties of Fresh MO-Ru and MO-Ru after 5 cycles materials.

	A_{BET} ($m^2.g^{-1}$)	V_{TOTAL} ($cm^3.g^{-1}$)	D_{MESO} (nm)
Fresh MO-Ru	79	0.204	11.7 (0.2082)
MO-Ru after 4 cycles	57	0.141	6.08 (0.143)

The isotherm of OM-Ru after the fifth cycle is shown in Figure 2. In this study, a reduction in total pore volume and a corresponding decrease in specific surface area were observed, along with a reduction in average pore size and pore volumes. The decrease in MO-Ru's catalytic activity after the fifth cycle could be attributed to the occupancy of the material's pores by water or organic molecules. It is likely that the catalytic process occurs more effectively in pores with an average size between 8 and 16 nm, which are predominantly present in the fresh MO-Ru but are nearly lost after repeated catalytic use.}

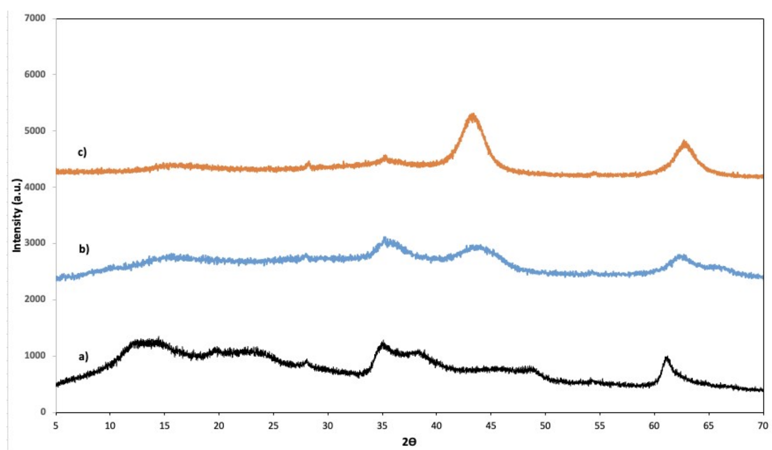


Figure SI6. Comparative XRD patterns of: (a) MO-Ru after 6 cycles, (b) Calcinated MO-Ru after 6 cycles and (c) Fresh MO-Ru.

The powder XRD patterns of calcined MO-Ru after six cycles exhibited diffraction patterns similar to those of the fresh MO-Ru, indicating that this type of material can be restructured through the so-called "memory effect." The catalytic activity of calcined MO-Ru after six cycles was tested again in the hydrogenation of levulinic acid (LA) using formic acid (FA) as the sole hydrogen source and H_2O under optimized reaction conditions (150°C, 1.5 hours, [Ru] 0.5 mol%). The catalyst achieved 97% conversion of LA with 95% selectivity toward GVL for two cycles. However, after the third cycle, LA conversion decreased to 78% with a 77% yield of GVL.