Supplementary Information:

Highly selective conversion of phenol to cyclohexanol over increased acidity on the Ru/Nb_2O_5-nC18PA catalysts in biphasic system under mild condition

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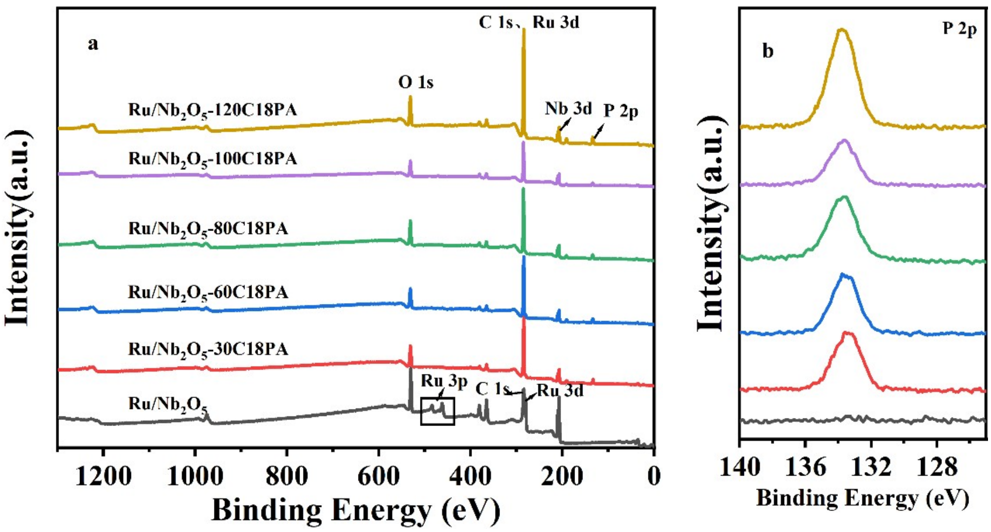

Fig. S1 XPS spectra in all element and P 2p regions for the Ru/Nb_2O_5-nC18PA catalysts.

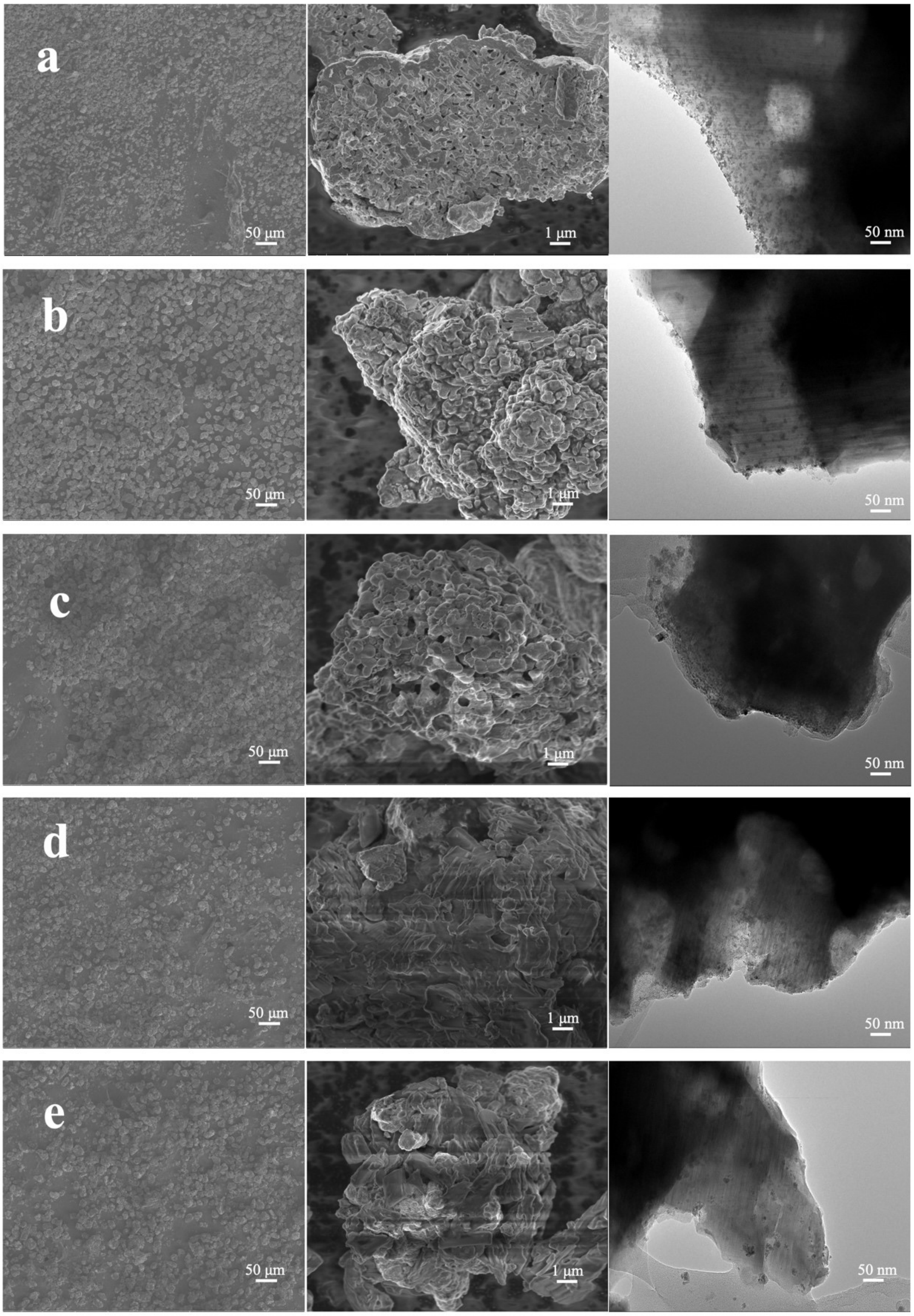

Fig. S2 SEM images (first column and second column) and TEM images (third column) of the Ru/Nb_2O_5 (a), Ru/Nb_2O_5-30C18PA (b), Ru/Nb_2O_5-60C18PA (c), Ru/Nb_2O_5-80C18PA (d), Ru/Nb_2O_5-120C18PA (e) catalyst.

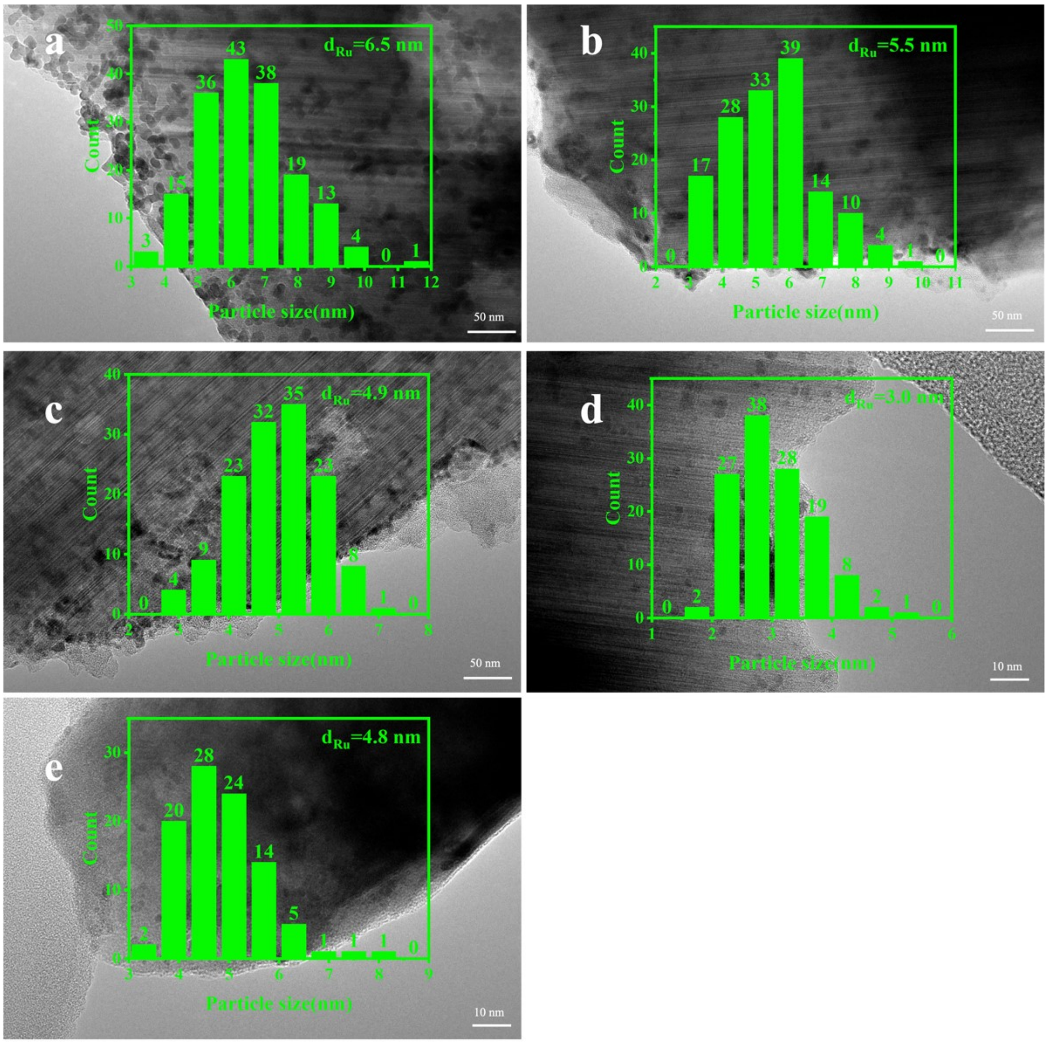

Fig. S3 TEM images of the Ru/Nb_2O_5 (a), Ru/Nb_2O_5-30C18PA (b), Ru/Nb_2O_5-60C18PA (c), Ru/Nb_2O_5-80C18PA (d), Ru/Nb_2O_5-120C18PA (e) catalyst with the corresponding Ru nanoparticle size distribution histogram.

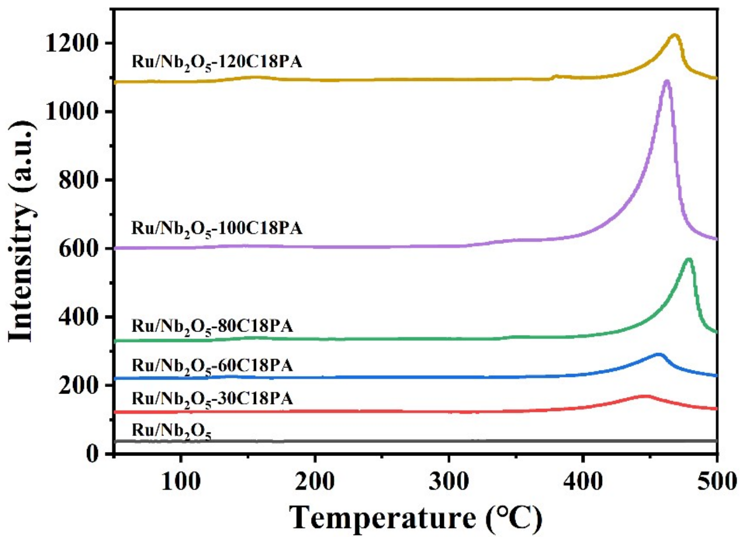

Fig. S4 NH_3-TPD profiles of the Ru/Nb_2O_5-nC18PA catalysts.

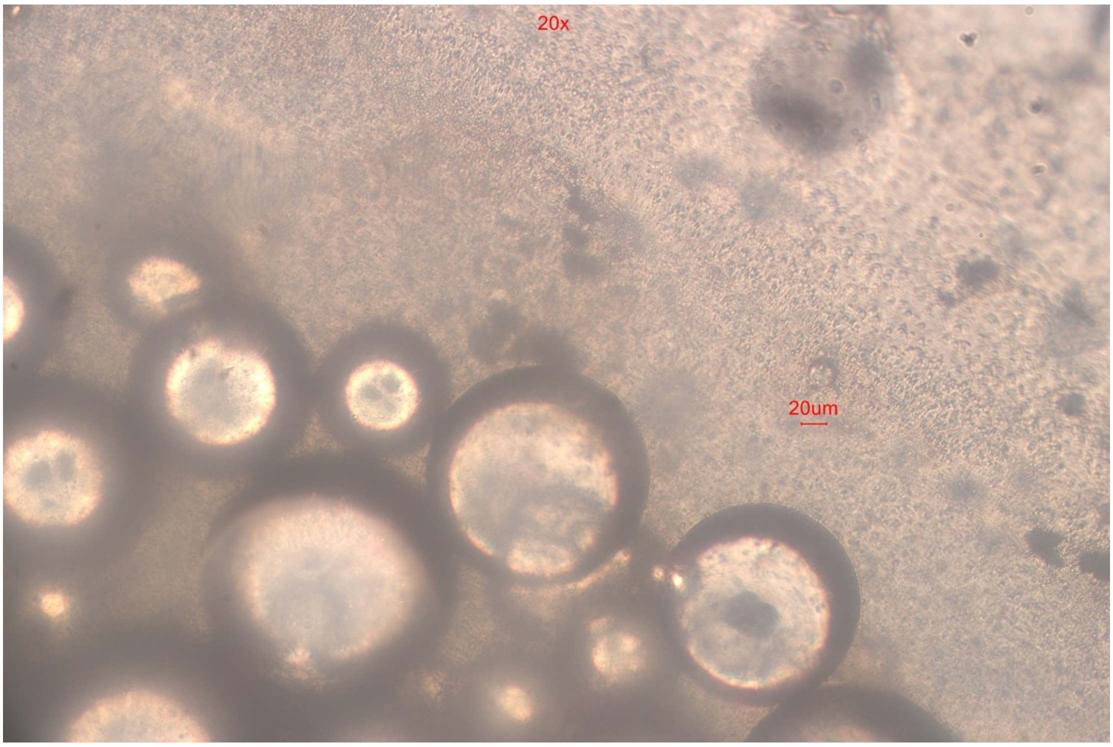

Fig. S5 Color photograph of the emulsion prepared from the Ru/Nb_2O_5-100C18PA catalyst.

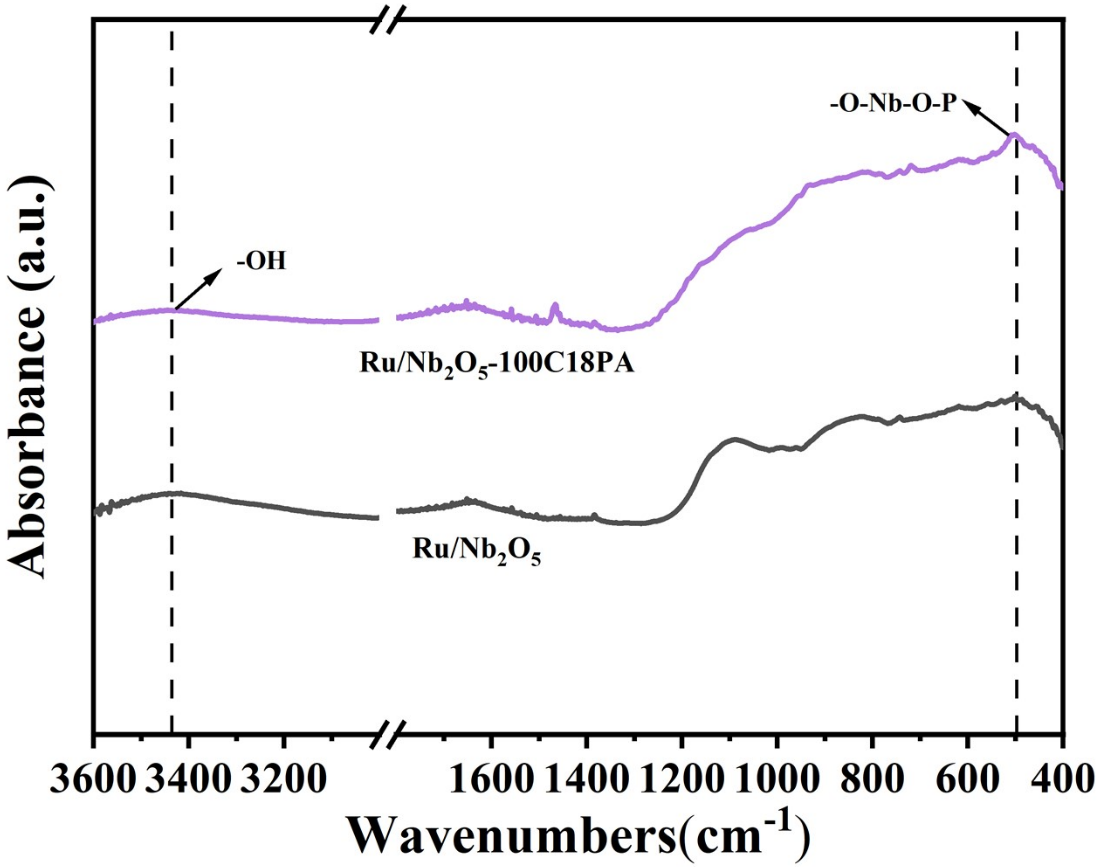

Fig. S6 FTIR spectra for the Ru/Nb_2O_5 and Ru/Nb_2O_5-100C18PA catalysts

Table S1 Summary of the binding energy in the high-resolution XPS Ru 3d and C 1s spectra of the Ru/Nb_2O_5-nC18PA catalysts.

Catalysts	Ru $3d_{3/2}$			C 1s		
	Ru (0)	Ru (+4)	Ru (0) (%)[#]	C-C	C-O	C=O
Ru/Nb_2O_5	284.35	285.17	10.85	283.82	284.80	286.01
Ru/Nb_2O_5-30C18PA	284.28	284.97	14.48	283.74	284.63	285.68
Ru/Nb_2O_5-60C18PA	284.17	284.85	18.55	283.53	284.49	285.40
Ru/Nb_2O_5-80C18PA	284.45	285.13	22.67	284.33	284.81	286.18
Ru/Nb_2O_5-100C18PA	284.39	285.06	27.96	283.91	284.73	285.36
Ru/Nb_2O_5-120C18PA	284.36	284.95	23.20	284.09	284.66	285.74

[#] Ru (0) *100 / (Ru (0) + Ru (+4)).

Table S2 Summary of the binding energy and calculated atomic concentrations in the high-resolution XPS O 1s spectra of the Ru/Nb_2O_5-nC18PA catalysts.

Catalysts	O 1s		
	O_α(eV)	O_β (eV)	O_α/ (O_α+O_β) (%)
Ru/Nb_2O_5	530.99	530.22	38.80
Ru/Nb_2O_5-30C18PA	532.25	530.53	46.67
Ru/Nb_2O_5-60C18PA	532.33	530.53	49.62
Ru/Nb_2O_5-80C18PA	532.12	530.49	51.32
Ru/Nb_2O_5-100C18PA	532.20	530.39	51.55
Ru/Nb_2O_5-120C18PA	532.48	530.63	50.80

Table S3 Summary of the binding energy and full-width half-maximum (FWHM) values in the high-resolution XPS Nb 3d spectra of the Ru/Nb_2O_5-nC18PA catalysts.

Catalysts	Nb_2O_5 $3d_{5/2}$(eV)		Nb_2O_5 $3d_{3/2}$(eV)	
	BE (eV)	FWHM (eV)	BE (eV)	FWHM (eV)
Ru/Nb_2O_5	207.29	1.29	210.03	1.24
Ru/Nb_2O_5-30C18PA	207.24	1.38	209.97	1.35
Ru/Nb_2O_5-60C18PA	207.19	1.38	209.93	1.32
Ru/Nb_2O_5-80C18PA	207.34	1.36	210.07	1.32
Ru/Nb_2O_5-100C18PA	207.27	1.32	210.01	1.28
Ru/Nb_2O_5-120C18PA	207.20	1.37	209.93	1.32

Table S4 Surface areas and porosities of the Ru/Nb_2O_5-nC18PA catalysts.

Catalysts	S_{BET}[a] (m^2/g)	S_{micro}[b] (m^2/g)	V_{total}[c] (cm^3/kg)	Average pore diameter (nm)
Nb_2O_5	72.07	0.00	0.043	2.37
Ru/Nb_2O_5	38.08	0.00	0.030	3.16
Ru/Nb_2O_5-30C18PA	33.63	0.00	0.027	5.04
Ru/Nb_2O_5-60C18PA	25.48	0.00	0.019	5.50
Ru/Nb_2O_5-80C18PA	22.84	0.00	0.028	4.87
Ru/Nb_2O_5-100C18PA	12.94	0.13	0.015	4.49
Ru/Nb_2O_5-120C18PA	14.10	0.11	0.024	1.65

[a] Specific surface area calculated by Brunauer-Emmett-Teller (BET) equation.

[b] Specific surface area of micro-pores calculated by the density functional theory (DFT) method.

[c] Total pore volume determined at P/P 0 = 0.99.

Table S5 The contact angles and average particle size of Ru of the Ru/Nb_2O_5-nC18PA catalysts.

Catalysts	The contact angles(°)	Average particle size of Ru（nm）
Ru/Nb_2O_5	0	6.47
Ru/Nb_2O_5-30C18PA	105.6	5.52
Ru/Nb_2O_5-60C18PA	107.5	4.94
Ru/Nb_2O_5-80C18PA	103.1	3.02
Ru/Nb_2O_5-100C18PA	104.3	2.00
Ru/Nb_2O_5-120C18PA	100.4	4.81

Supplementary Note 1: Method of recycling catalysts

After each batch of the catalytic reaction is completed, the reactor is placed in a water tank and quickly cooled to room temperature. Then open the reactor and directly add the next batch of phenol to it, and finally proceed to the next catalytic reaction.