Supporting Information

Synergistic effects of phosphorus/nitrogen co-doping and morphology regulation enhance the catalytic hydrogenation performance of Ru-based catalysts for benzoic acid

*Zijian Wang,[1] Yuyao Wang,[1] Zhengyu Pan,[1] Guoquan Zhou,[2] Lele Yan,[1] Lina Zhu,[1] Zheng Fang,[1] Tongyang Song,[1] Xianlang Chen *[1] and Rongrong Li *[1]*

[1]Engineering Research Center of Recycling & Comprehensive Utilization of Pharmaceutical and Chemical Waste of Zhejiang Province, Taizhou University, Taizhou 318000, Zhejiang, China.
[2]School of Materials and Chemical Engineering, Ningbo University of Technology, Ningbo City, Zhejiang Province 315211, P. R. China.

*Corresponding author: Email: chenxianlangaini@163.com (X. Chen); lrr@tzc.edu.cn (R. Li)

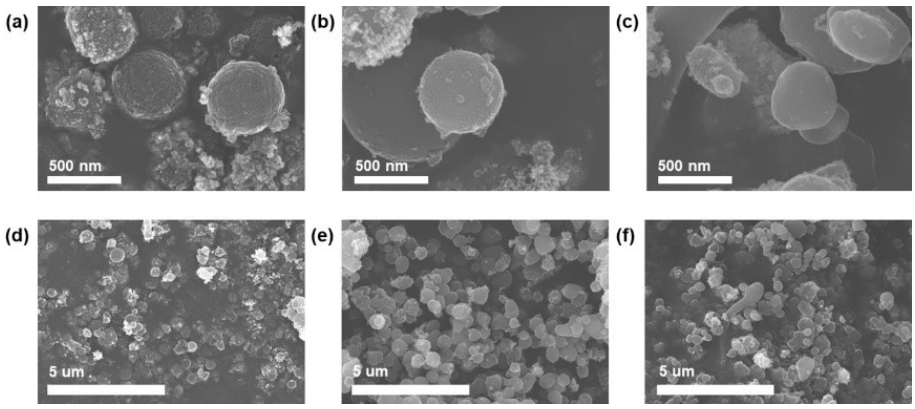

Fig. S1 SEM images of (a, d) Ru/PPNC-1, (b, e) Ru/PPNC-2, (c, f) Ru/PPNC-3.

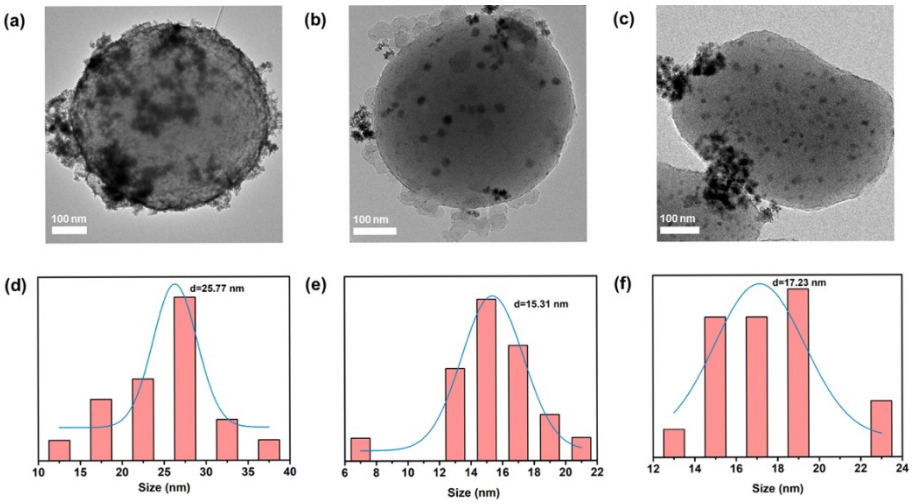

Fig. S2 TEM images of (a) Ru/PPNC-1, (b) Ru/PPNC-2, (c) Ru/PPNC-3 and he corresponding particle size distribution of (d) Ru/PPNC-1, (e) Ru/PPNC-2 and (f) Ru/PPNC-3, respectively.

Table S1 Results of metal dispersion of catalysts.

Sample	Metal Dispersion
Ru/PPNC-1	20.58%
Ru/PPNC-2	25.21%
Ru/PPNC-3	22.51%

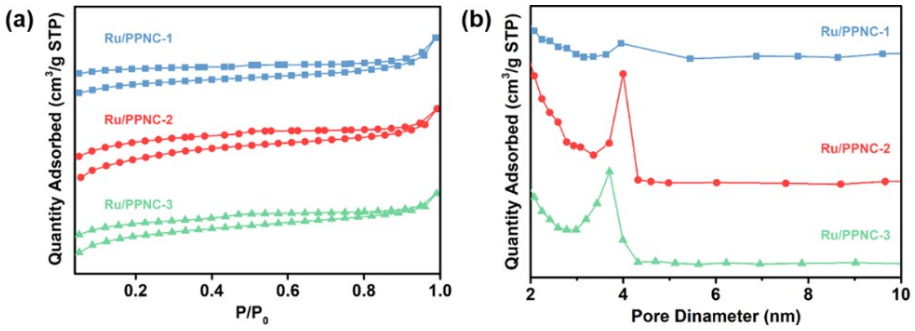

Fig. S3 (a) N_2 adsorption-desorption isotherms analysis showing catalysts possess a mesoporous structure. (b) BJH pore size distribution verifies the mesoporous characteristics of the samples.

Table S2 Specific surface area and pore structure results of a series of catalysts.

Sample	S_{BET}/（m^2/g)	V_{pore}(cm^3/g)	$R_{average}$/（nm）
Ru/PPNC-1	171.6	0.1096	2.5547
Ru/PPNC-2	416.4	0.2270	2.1810
Ru/PPNC-3	354.9	0.1933	2.1781

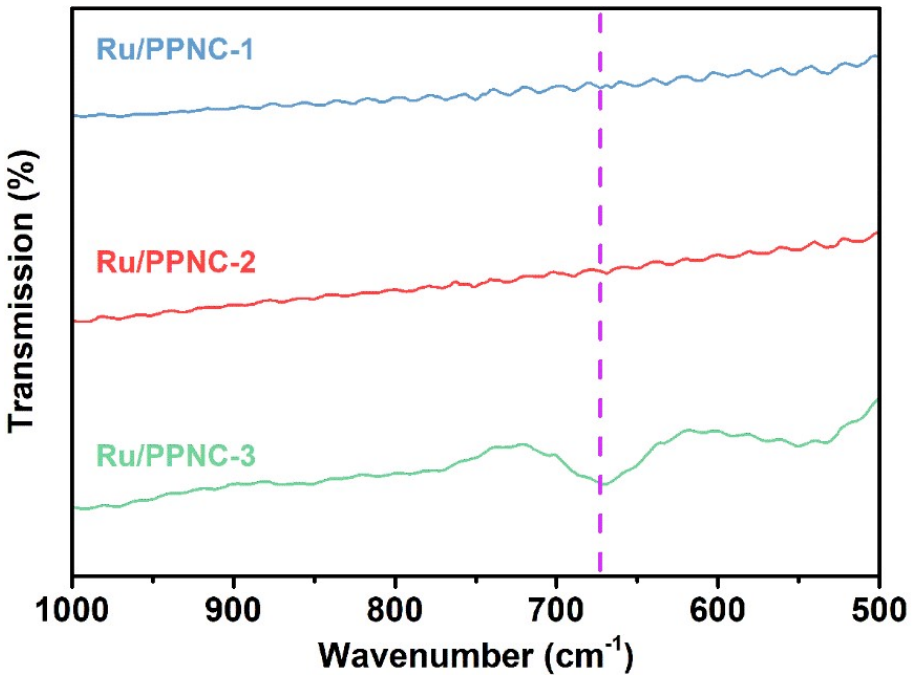

Fig. S4 Local magnification of FTIR pattern.

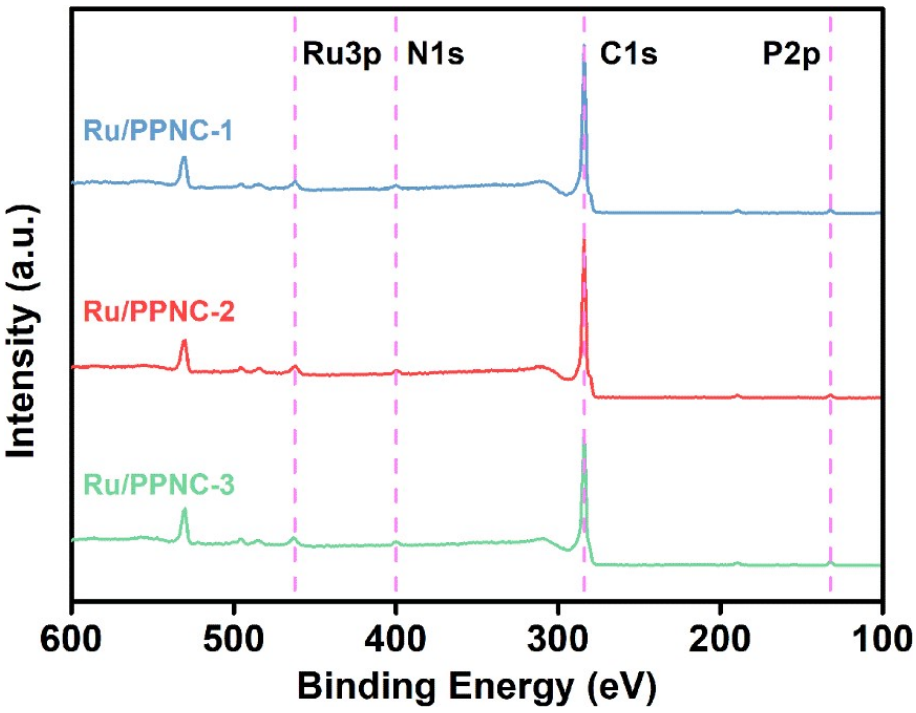

Fig. S5 XPS high-resolution spectra the surface compositions of catalysts.

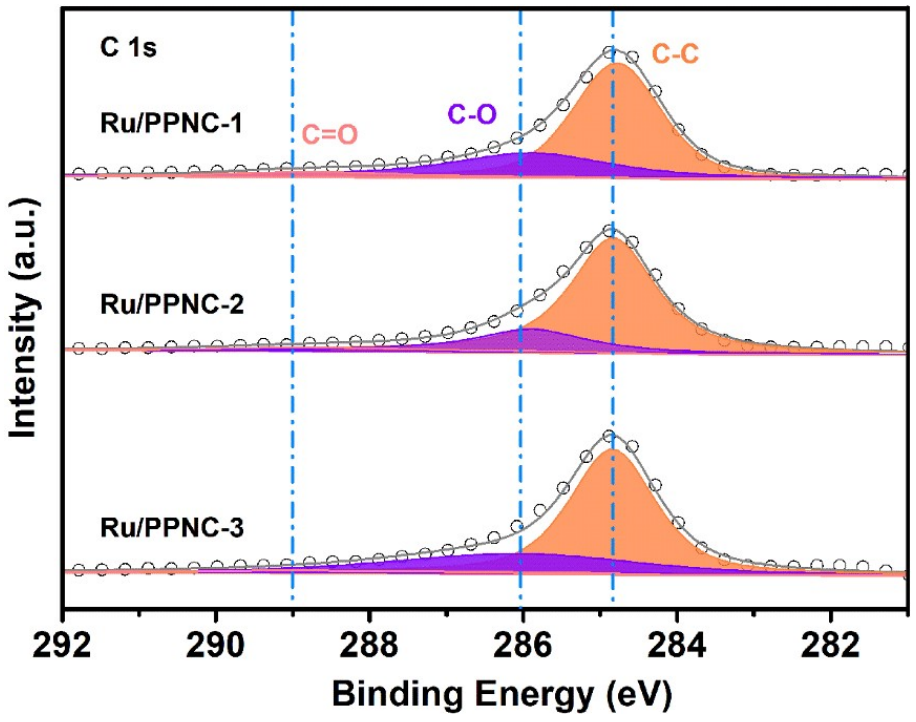

Fig. S6 XPS spectra of C 1s of Ru/PPNC-1, Ru/PPNC-2 and Ru/PPNC-3.

Table S3 Element analysis results of the samples with different content of ICP.

Sample	Ru (wt%)
Ru/PPNC-1	2.05%
Ru/PPNC-2	1.71%
Ru/PPNC-3	2.00%

Table S4 Analysis results of N and P doping amounts of different samples in XPS.

Sample	N (wt%)	P (wt%)	N:P
Ru/PPNC-1	2.42	1.69	1.43
Ru/PPNC-2	2.32	1.71	1.36
Ru/PPNC-3	2.66	2.04	1.30

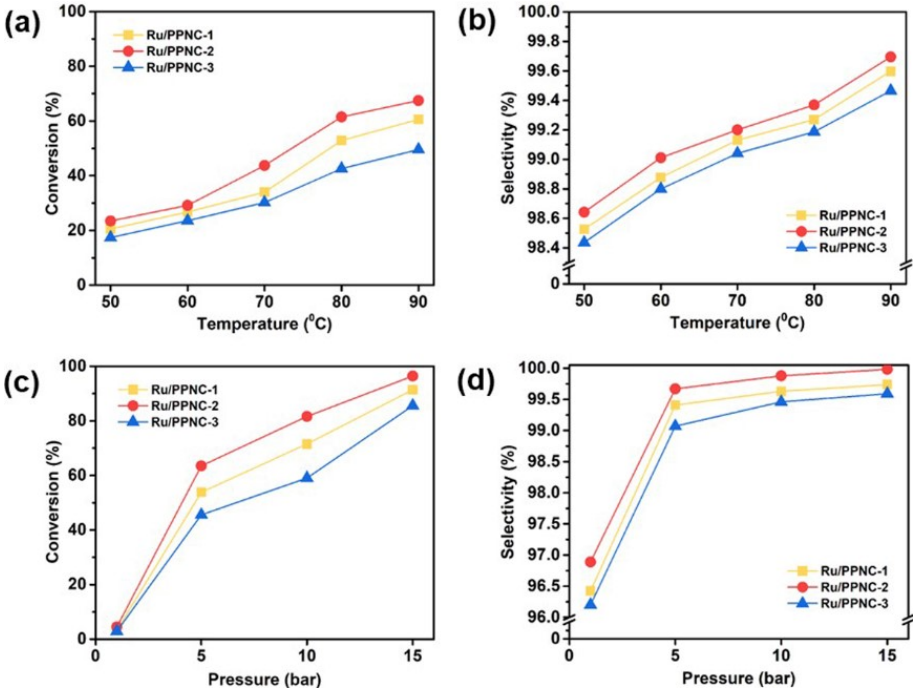

Fig. S7 Performance of the prepared series of catalysts at different temperatures and H_2 pressure (a) BA conversion, (b) CCA selectivity. Reaction conditions: catalyst, 10 mg; BA 12.2 mg, solvent, water (1 mL); hydrogen pressure, 0.5 MPa; time, 60min. (c) BA conversion, (d) CCA selectivity. Reaction conditions: catalyst, 10 mg; BA 12.2 mg, solvent, water (1 mL); temperature, 80 °C; time, 60 min.

Table S5 Hydrogenation of BA over Ru/PPNC-2 catalyst in different solvents.

Entry	Solvents	t (min)	T (℃)	Conversion (%)	Selectivity (%)
1	H_2O	60	80	81.64	99.89
2	Dioxane	60	80	4.59	28.39
3	Cyclohexane	60	80	19.80	84.76
4	Ethanol	60	80	42.67	91.92
5	THF	60	80	40.60	81.20
6	Toluene	60	80	6.67	64.85
7	Acetonitrile	60	80	2.01	42.49
8	Hexyl hydride	60	80	44.26	95.86

Reaction conditions: 0.1 mmol BA, 10 mg Ru/PPNCC-2, 1 mL solvent, 1 MPa H_2.

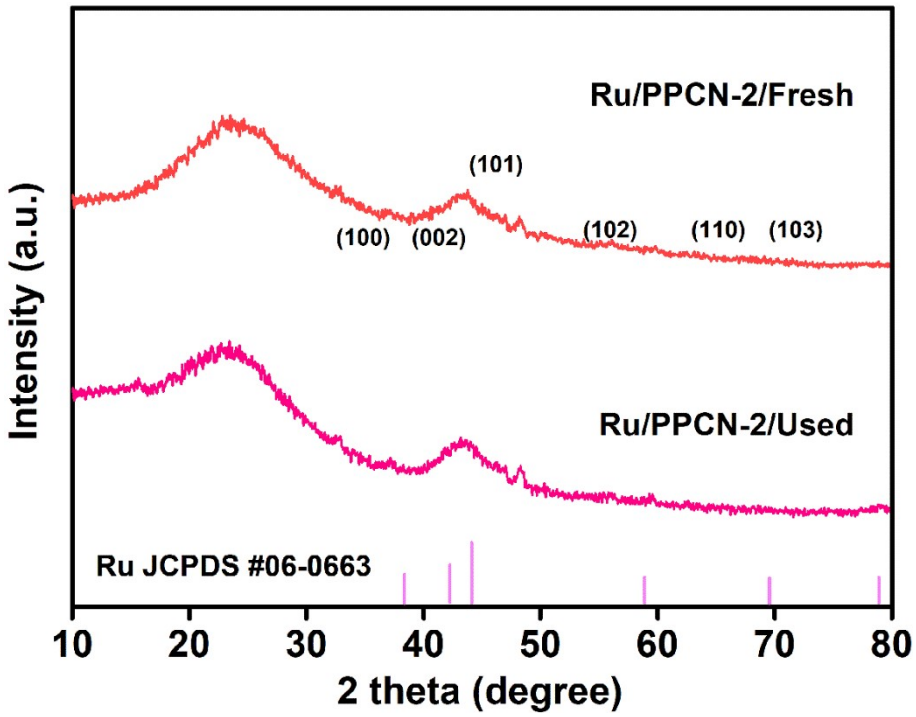

Fig. S8 XRD spectra of new catalysts and catalysts reused.

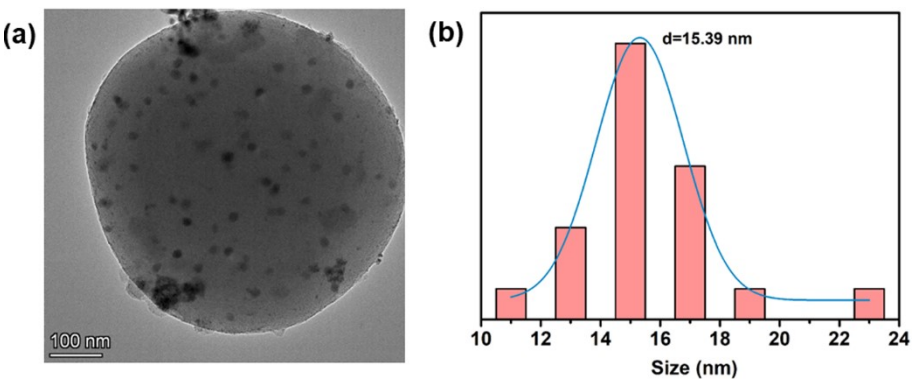

Fig. S9 TEM images of Ru/PPNC-2 reused.