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# Sol-gel preparation of crystalline $Ni_{12}P_5$/N-doped carbon and amorphous Ni-P-C catalysts and their high catalytic performances toward hydrogenation reduction reaction of 4-nitrophenol

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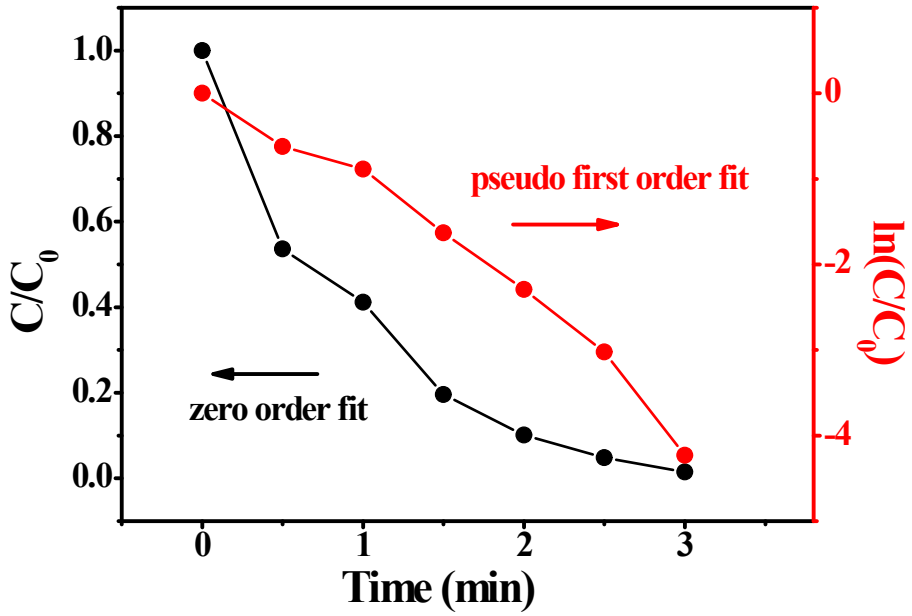


**Figure S1.** Comparison of zero order fit and pseudo order fit of the hydrogenation reaction of 4-NP over the $Ni_{12}P_5$/N-doped carbon catalyst being calcinated at 800 °C. The molar ratio of NaBH4:4-NP is 1000:1 and the mass of the catalyst is 0.05 mg.

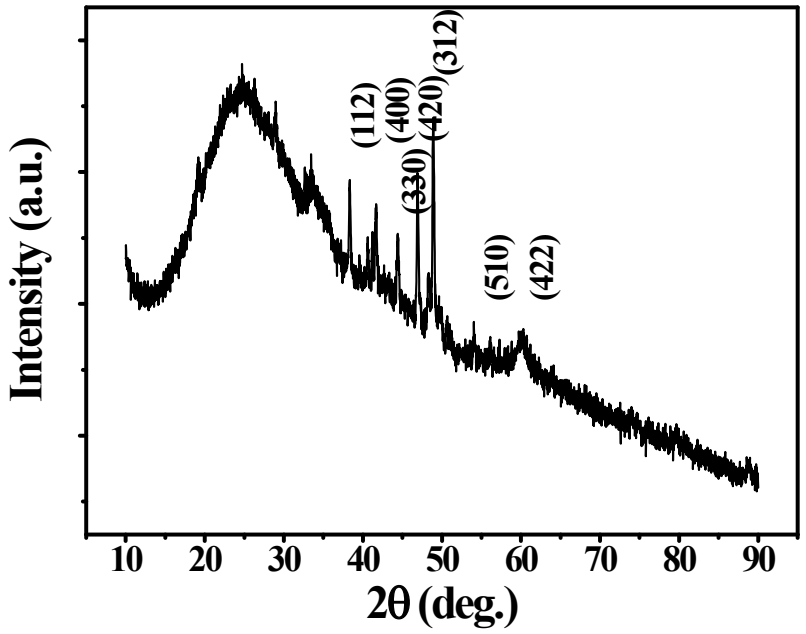


**Figure S2.** XRD profile of the recycled $Ni_{12}P_5$/N-doped carbon catalyst where the

original catalyst is prepared at 800 °C

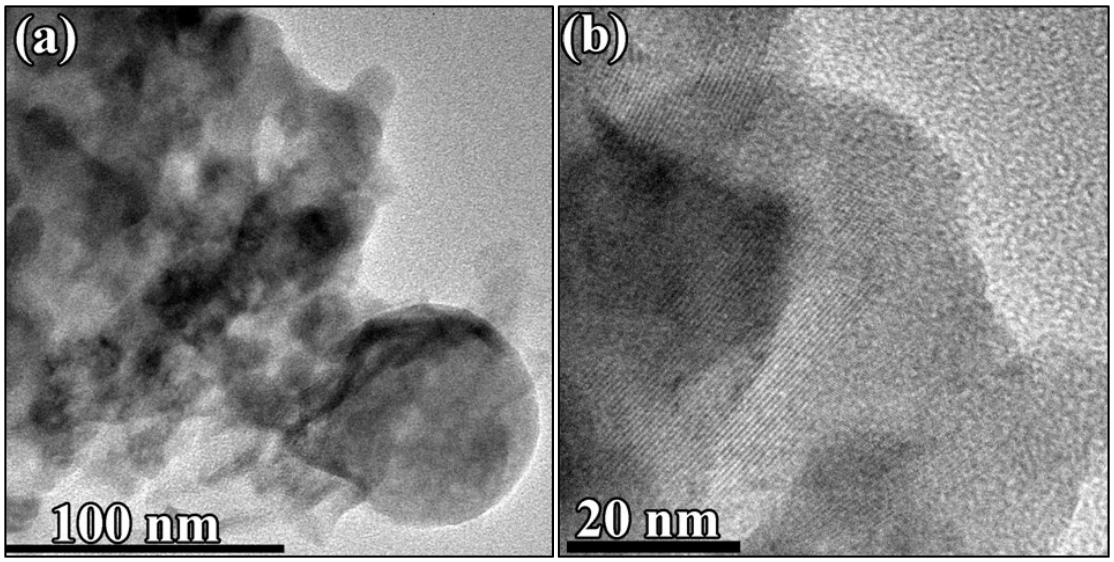


**Figure S3.** TEM image of the recycled $Ni_{12}P_5$/N-doped carbon catalyst where the original catalyst is prepared at 800 °C.

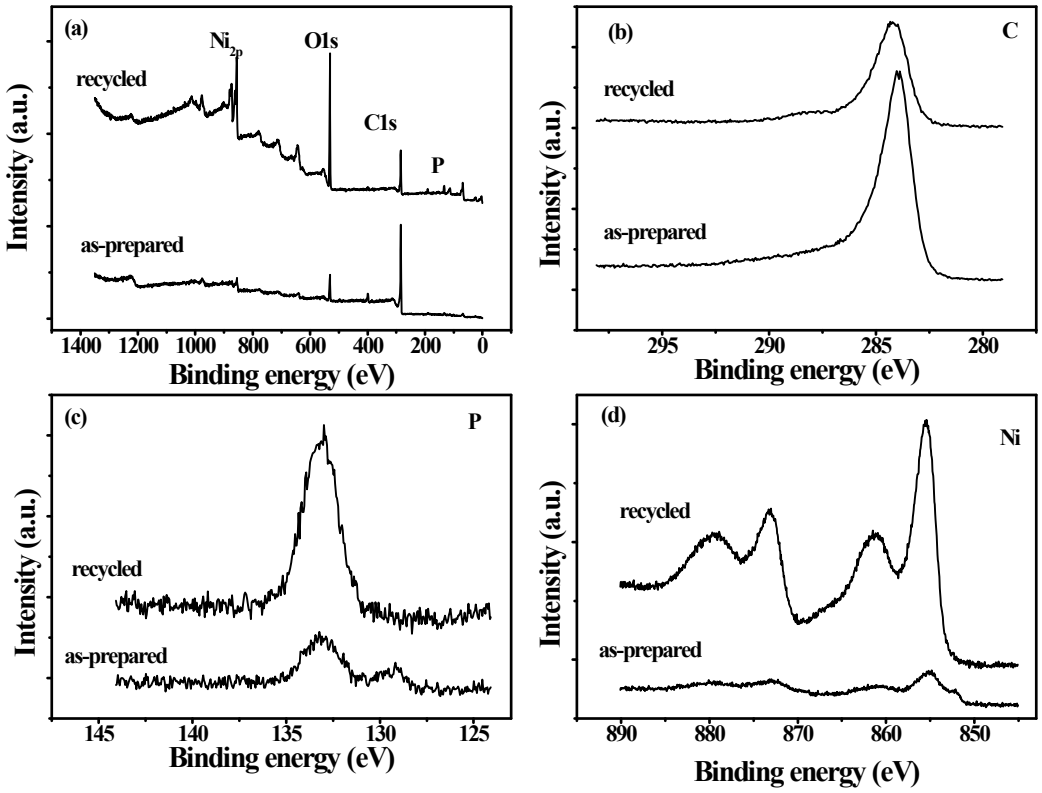


**Figure S4.** XPS analysis results the recycled $Ni_{12}P_5$/N-doped carbon catalyst and the original catalyst being prepared at 800 °C.

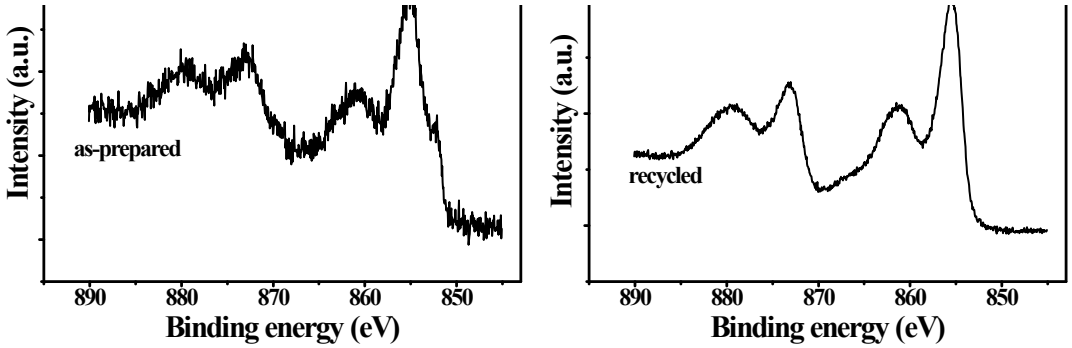


**Figure S5.** XPS profiles of Ni of the recycled $Ni_{12}P_5$/N-doped carbon catalyst and the original catalyst being prepared at 800 °C.

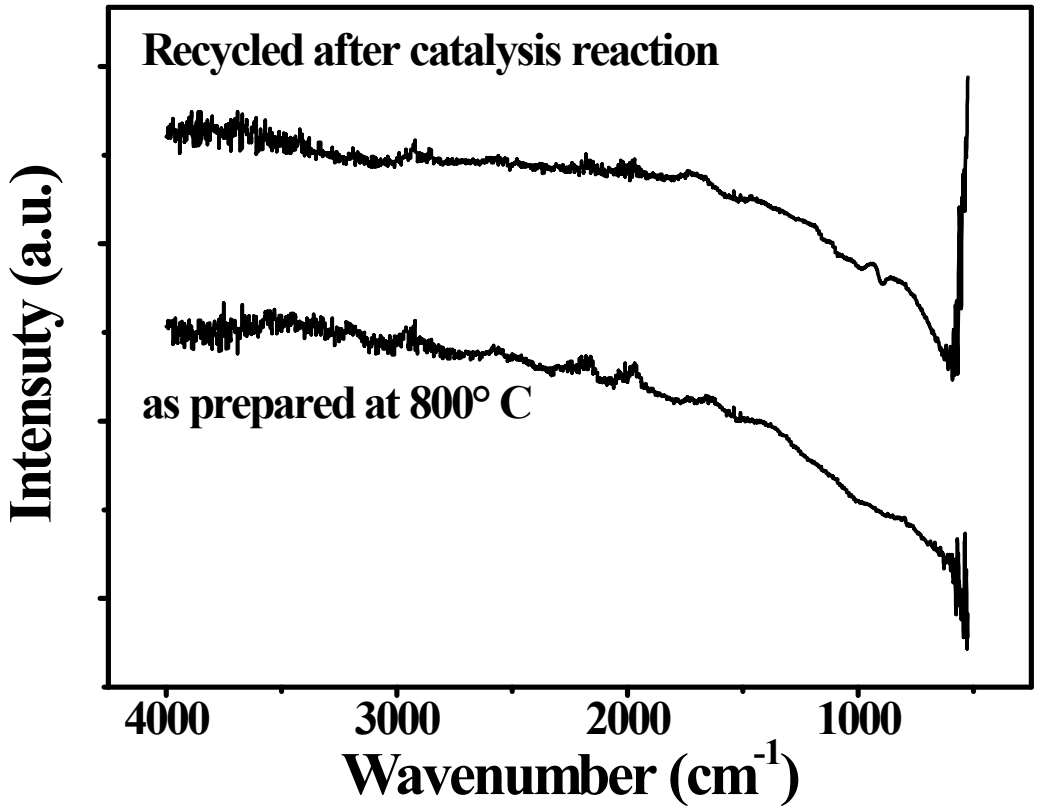


**Figure S6.** FTIR plots of the recycled $Ni_{12}P_5$/N-doped carbon catalyst and the original catalyst being prepared at 800 °C.

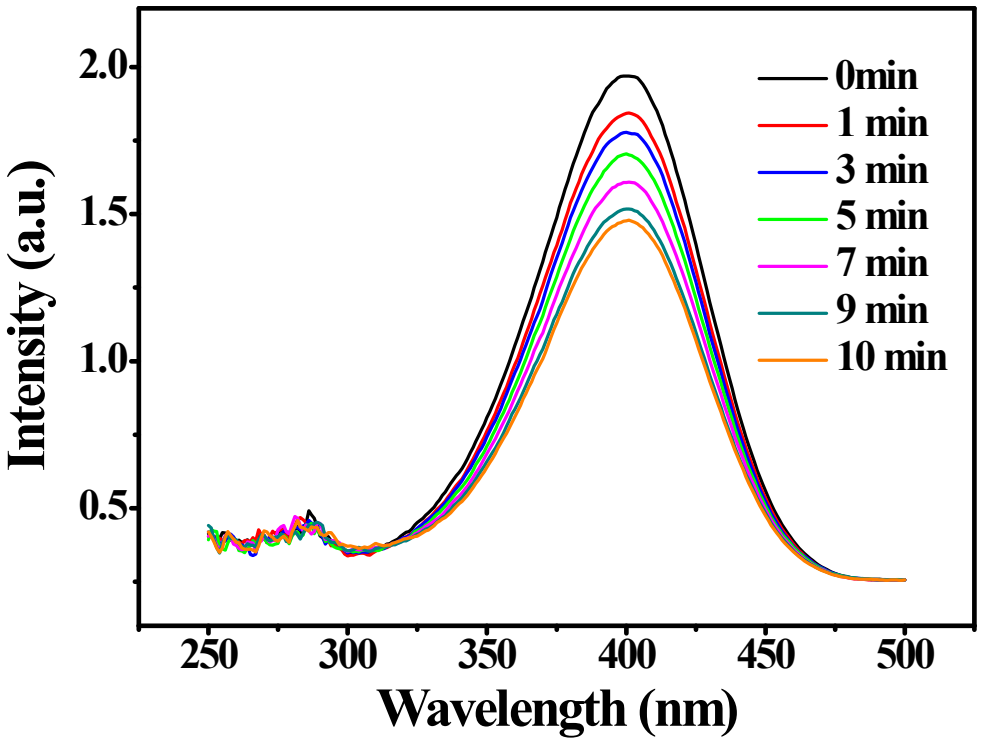


**Figure S7**. UV-vis spectra for the hydrogenation reduction of 4-NP over the catalysts being calcinated at and 800 °C by using EDTA, (NH4)2HPO4, urea, PVP, and de-ionized water. The molar ratio of $NaBH_4$:4-NP=1000:1, mass of the catalysts is 0.2 mg.

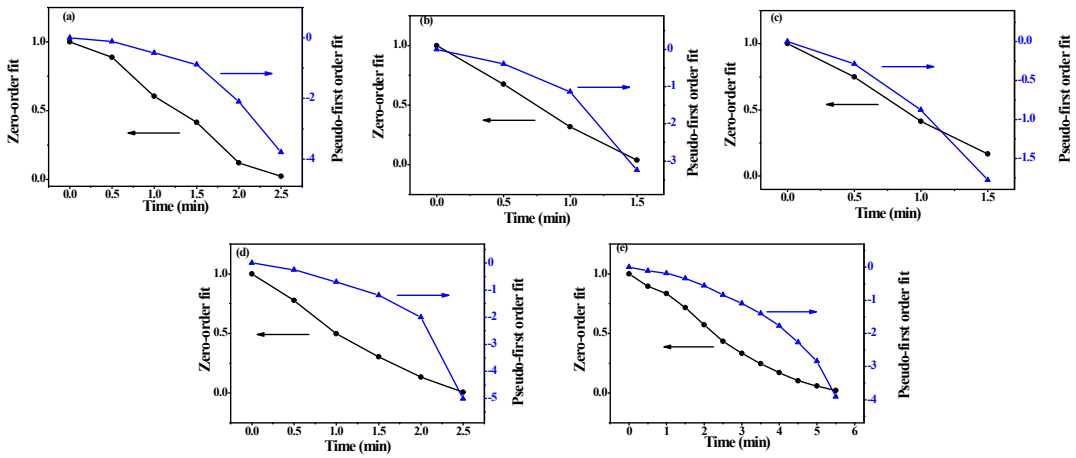


**Figure S8.** Comparison between pseudo zero-order linear fit and pseudo first-order linear fit of the hydrogenation of 4-NP over the amorphous Ni-P-C catalysts being

calcined at 350 (a), 450 (b), 550 (c), 600 (d) and 700 °C (e), respectively.

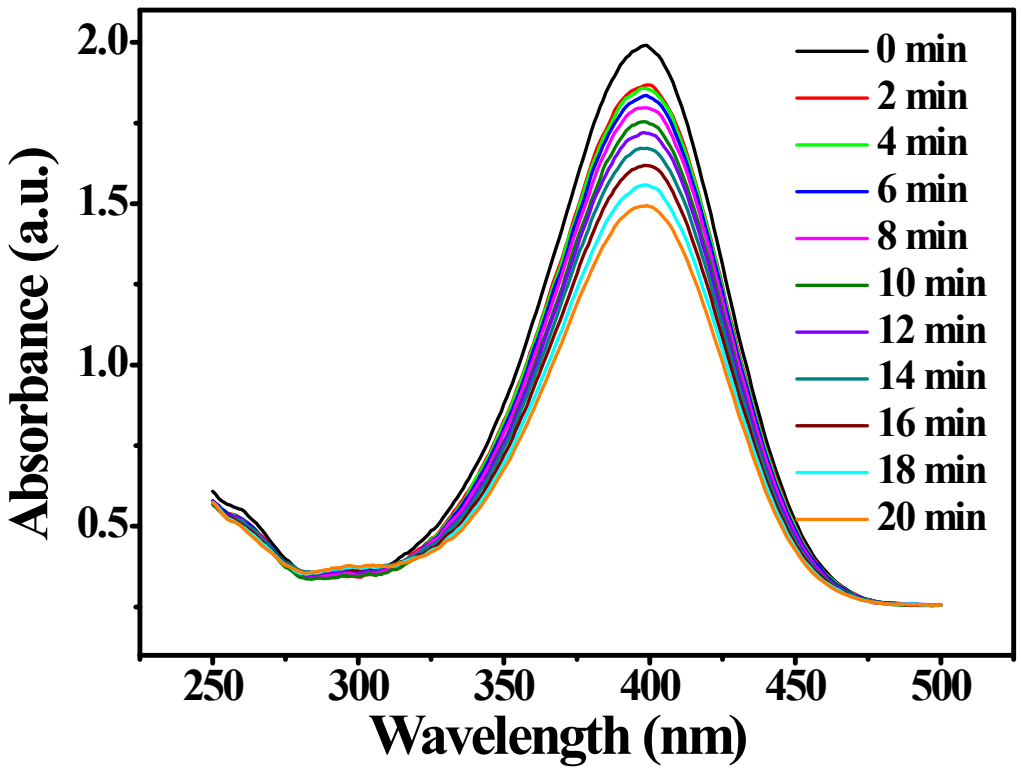


**Figure S9.** UV-vis spectra for the hydrogenation reduction of 4-NP over the product being calcinated at 600 °C by using EG, phosphoric acid, PVP and de-ionized water in the absence of $Ni(NO_3)_2 \cdot 6H_2O$. The mass of the catalysts is 0.2 mg during the catalytic measurements, and the molar ratio of $NaBH_4$:4-NP is 1590:1.