Controllable synthesis of Ni/SiO_2 hollow spheres and excellent catalytic performance in 4-introphenol reduction

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Table S1 Experimental conditionsfor the synthesis of SiO_2 particles with different sizes [a]

SiO_2 (nm)	V(TEOS)	V(H_2O)	V(NH_3)	V(C_2H_5OH)
140	14	49.8	27.9	277.2
210	14	31.4	183	119.8
350	14	28.2	164.8	106.4
580	14	4	117.8	88.2

a V: volume (mL)

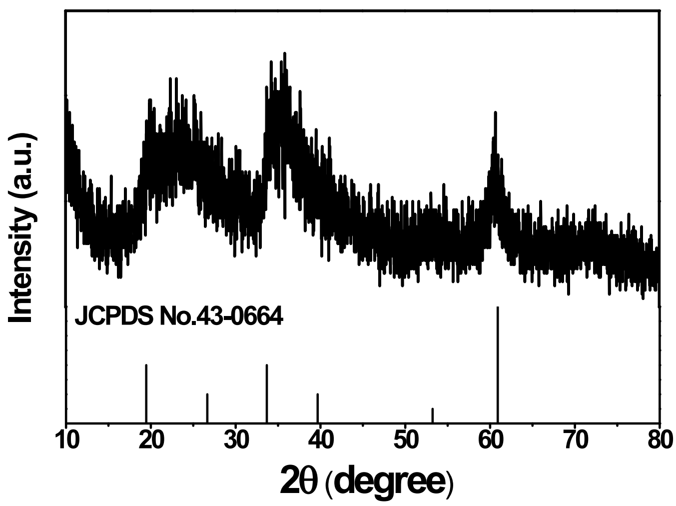

Fig. S1 XRD pattern of nickel silicate.

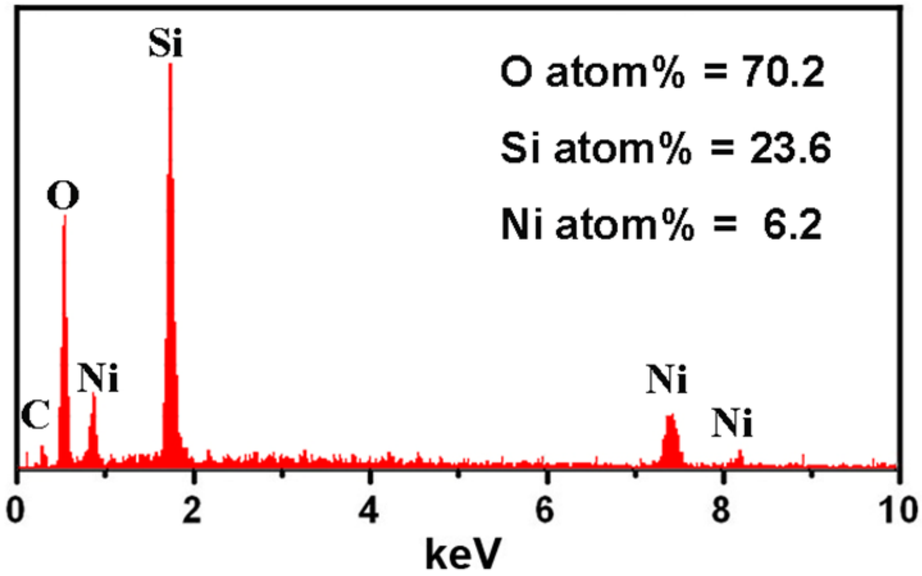

Fig. S2 EDS spectrum of nickel silicate.

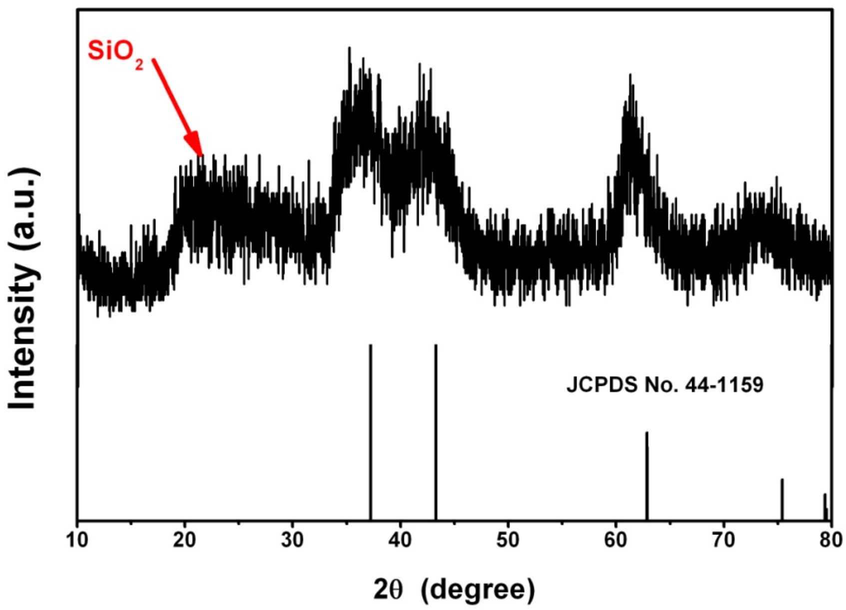

Fig. S3 XRD pattern of NiO/SiO_2 and the standard data of rhombohedral phased NiO.

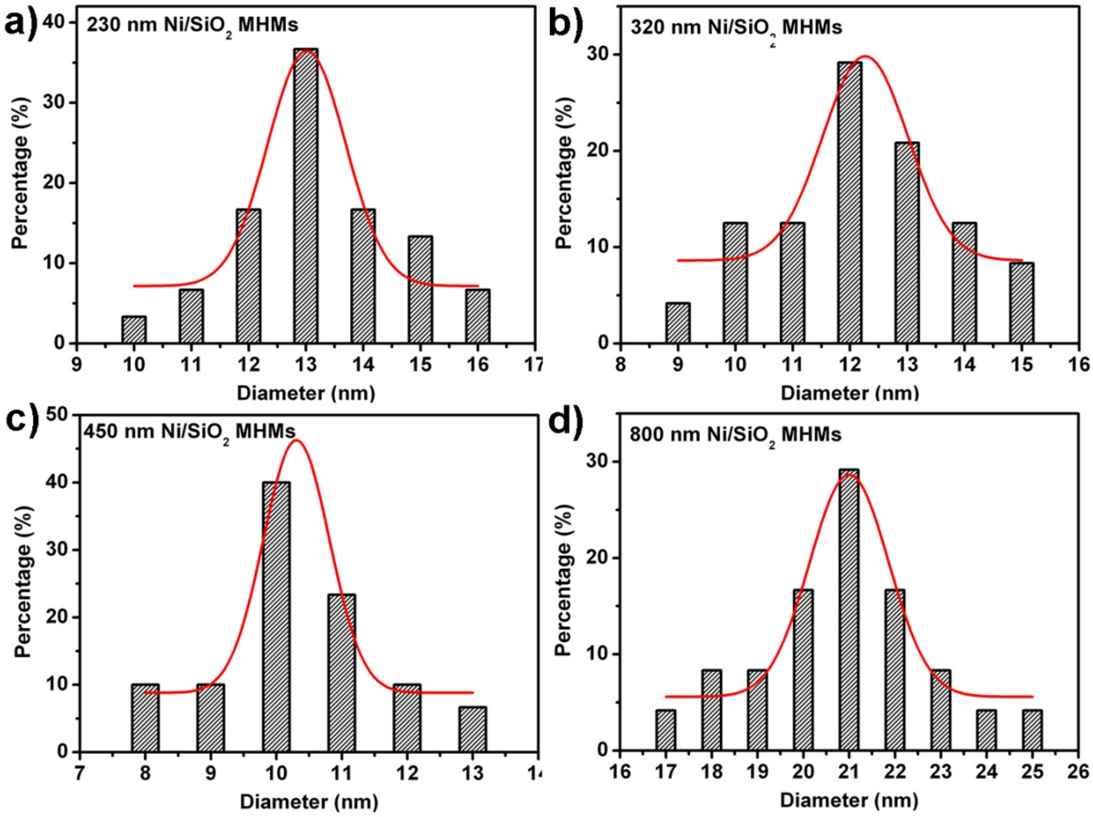

Fig. S4 Size distribution histogram of the Ni NPs calculated from a single Ni/SiO_2 MHMs with the diameter of a) 230 nm, b) 320 nm, c) 450 nm and d) 800 nm.

Fig. S5 photograph for the magnetic separation of Ni/SiO_2 MHMs.

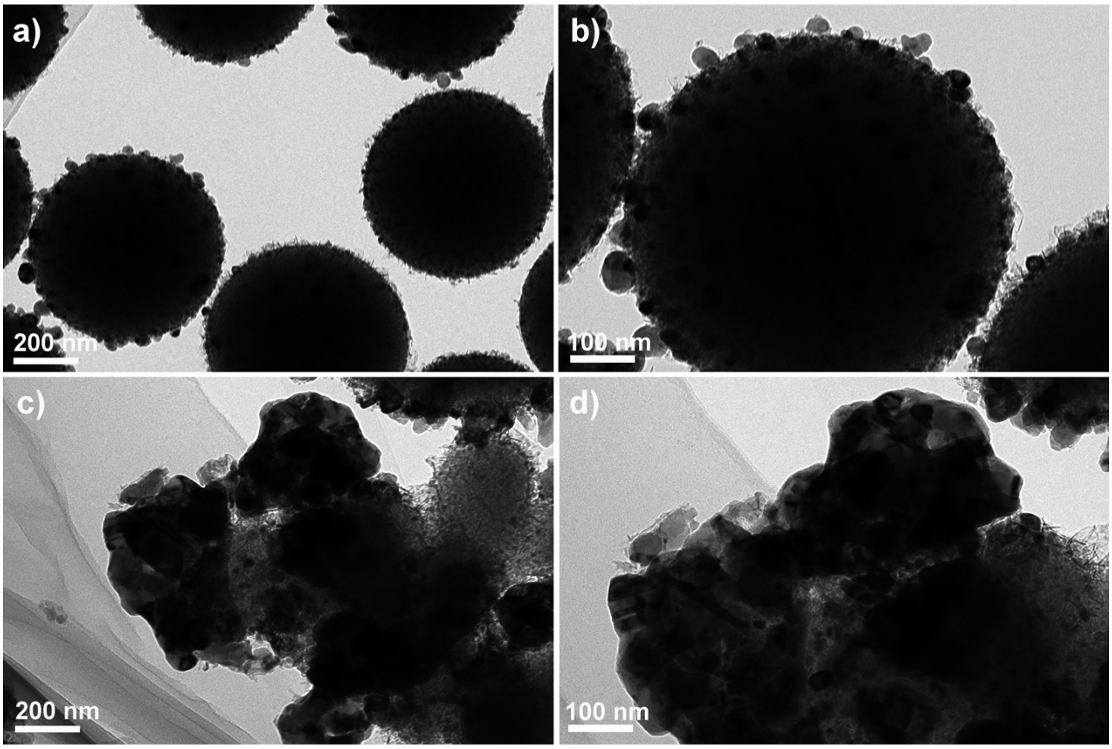

Fig. S6 TEM images of Ni/SiO_2 synthesized by wet impregnation (a, b) and bare Ni NPs synthesized by calcination and reduction of $Ni(NO_3)_3$ (c, d).

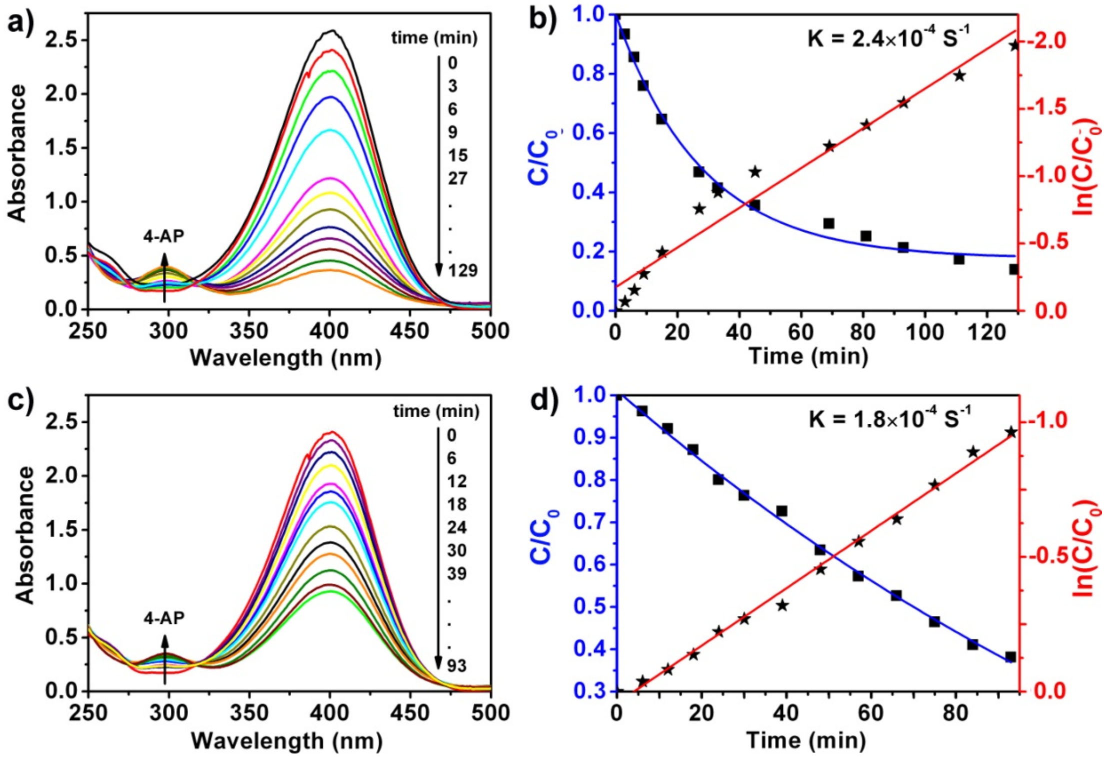

Fig. S7 UV-vis spectra of the catalytic reduction of 4-NP to 4-AP developed at different reaction times over Ni/SiO_2 synthesized by wet impregnation (a) and bare Ni NPs synthesized by calcination and reduction of $Ni(NO_3)_3$ (b); C/C_0 and $ln(C/C_0)$ versus time for the reduction of 4-NP over Ni/SiO_2 synthesized by wet impregnation (c) and bare Ni NPs synthesized by calcination and reduction of $Ni(NO_3)_3$ (d), the ratio of 4-NP concentration (Ct at time t) to its initial value C_0 is directly represented by the relative intensity of the respective absorption peak at 400 nm.

Table S2 The ICP data of Ni/SiO_2 MHMs with different size before and after catalytic reaction.

	Ni (μg/mg)	Si (μg/mg)
230 nm Ni/SiO_2 MHMs	14.6	24.3
320 nm Ni/SiO_2 MHMs	16.4	29.5
450 nm Ni/SiO_2 MHMs	13.2	27.6
800 nm Ni/SiO_2 MHMs	14.4	25.2
230 nm Ni/SiO_2 MHMs after recycling	12.4	25.6

For calculating the dispersion of Ni/SiO_2 HMHs, the equation can be formulated as follows (see Ref. S1 and S2)

The number of nickel particles $N_1 = \frac{d_{Ni}}{\frac{2}{3}\pi(\frac{d_{Ni}}{2})^2\rho_{Ni}}$

The overall surface area of Ni particles $S = 2\pi(\frac{d_{Ni}}{2})^2 N_1$

Dispersion $= \frac{N_S}{N_T} = \frac{Sk}{n_{Ni}N_A}$

Where $\rho_{Ni} = 8.90 \times 10^3$ kg m^{-3}

N_S = total number of surface nickel atoms

N_T = total number of nickel atoms

The nickel atom density (k) is 1.54×10^{19} m^{-2}

$N_A = 6.02 \times 10^{23}$ mol^{-1}

$n_{Au} = m_{Au}/M_{Au}$

Therefore, the equation can be written as:

Dispersion $= \frac{10.06}{d_{Ni}} = \frac{5.03}{r_{Ni}}$

References

1 J. R. Anderson, *Structure of Metallic Catalysts*, Academic Press, 1975

2 Q. Bi, X. Du, Y. Liu, Y. Cao, H. He and K. Fan, *J. Am. Chem. Soc.*, 2012, **134**, 8926.