Controllable synthesis of Ni/SiO$_2$ hollow spheres and excellent catalytic performance in 4-introphenol reduction

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Table S1 Experimental conditions for the synthesis of SiO$_2$ particles with different sizes $^a$

<table>
<thead>
<tr>
<th>SiO$_2$ (nm)</th>
<th>V(TEOS)</th>
<th>V(H$_2$O)</th>
<th>V(NH$_3$)</th>
<th>V(C$_2$H$_5$OH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>140</td>
<td>14</td>
<td>49.8</td>
<td>27.9</td>
<td>277.2</td>
</tr>
<tr>
<td>210</td>
<td>14</td>
<td>31.4</td>
<td>183</td>
<td>119.8</td>
</tr>
<tr>
<td>350</td>
<td>14</td>
<td>28.2</td>
<td>164.8</td>
<td>106.4</td>
</tr>
<tr>
<td>580</td>
<td>14</td>
<td>4</td>
<td>117.8</td>
<td>88.2</td>
</tr>
</tbody>
</table>

$^a$ V: volume (mL)
Fig. S1 XRD pattern of nickel silicate.
Fig. S2 EDS spectrum of nickel silicate.

O atom% = 70.2
Si atom% = 23.6
Ni atom% = 6.2
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 (C\(_t\) 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.

<table>
<thead>
<tr>
<th>Size</th>
<th>Ni (μg/mg)</th>
<th>Si  (μg/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230 nm Ni/SiO$_2$ MHMs</td>
<td>14.6</td>
<td>24.3</td>
</tr>
<tr>
<td>320 nm Ni/SiO$_2$ MHMs</td>
<td>16.4</td>
<td>29.5</td>
</tr>
<tr>
<td>450 nm Ni/SiO$_2$ MHMs</td>
<td>13.2</td>
<td>27.6</td>
</tr>
<tr>
<td>800 nm Ni/SiO$_2$ MHMs</td>
<td>14.4</td>
<td>25.2</td>
</tr>
<tr>
<td>230 nm Ni/SiO$_2$ MHMs after recycling</td>
<td>12.4</td>
<td>25.6</td>
</tr>
</tbody>
</table>
For calculating the dispersion of Ni/SiO$_2$ HMHs, the equation can be formulated as follows (see Ref. S1 and S2):

$$\frac{d_{Ni}}{2 \cdot \frac{d_{Ni}}{3} \frac{1}{2} \rho_{Ni}}$$

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

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

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 $1.54 \times 10^{19}$ m$^{-2}$

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

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

Therefore, the equation can be written as:

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

References
