Supporting Information

Toward High Practical Capacitance of Ni(OH)$_2$ Using Highly Conductive CoB Nanochain Supports

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Experimental

Material synthesis:

All reagents were of analytic grade, and double-distilled water was used throughout the experiments. To prepare the linear structured CoB sample, 0.35 mmol CoCl$_2$•6H$_2$O and 0.7 mmol NaOH were dissolved into 35 mL deionized water with intense stirring. Then 35 mL of 0.02 mol L$^{-1}$NaBH$_4$ solution was added drop-wise to the above solution with the fixed magnetic field intensity of ca. 0.4 Tesla under the vessel. The as-prepared CoB was rinsed with double-distilled water and ethanol alternately, and finally dried in vacuum oven at 40 °C for 8 h.

To prepare CoB@Ni(OH)$_2$, 20 mg of the as-prepared CoB was added to 20 mL deionized water, after which 0.1 mmol NiCl$_2$•6H$_2$O was dissolved into the suspension. The suspension was stirred at a rotation rate of 500 rpm for 1 h, wherein the following reactions occur:

Ni$^{2+}$ + Co $\rightarrow$ Ni + Co$^{2+}$

2Ni + O$_2$ + 2H$_2$O $\rightarrow$ 2Ni(OH)$_2$
The product was rinsed with double-distilled water and ethanol alternately, and finally dried in vacuum oven at 40 °C for 8 h.

**Characterization**

XRD patterns were recorded on a Shimadzu XD–3A (Japan) using filtered Cu-Kα radiation (\(\lambda = 0.15418\) nm) generated at 40 kV and 30 mA. Scans for 2Θ values were recorded at 4° min\(^{-1}\). Scanning electron microscopy (SEM) images were obtained using a Carl Zeiss Ultra Plus electron microscope. Transmission electron microscopy (TEM) high angle annular dark field scanning transmission electron microscopy (STEM) images of the catalysts were obtained using a JEOL (JEM-2000 FX) microscope operating at 200 kV. Specific surface area was determined by the Brunauer-Emmett-Teller (BET) method, and the density functional theory DFT method was employed for analyzing the full range of pore size distribution based on the sorption isotherms obtained on a Quantachrome Autosorb-1 volumetric analyzer. X-Ray Photoelectron Spectroscopy (XPS) spectra were generated using Thermo Scientific Escalab 250Xi. Binding energies were determined by referencing to the C 1 s peak at 285.0 eV. The molar ratios of Co, B Ni, in the bulk samples were determined by a Varian 720 Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

**Electrochemical measurements**

Cyclic voltammograms (CV) and galvanostatic charge/discharge tests on CoB@Ni(OH)\(_2\) were carried out in a three-electrode cell. The working electrode comprised 1 cm\(^2\) of a film containing CoB@Ni(OH)\(_2\), carbon black and poly(tetrafluoroethylene) with a mass ratio of 80:10:10, pressed into the Ni foam current collectors. An Hg/HgO (1.0 M KOH) reference electrode and an activated carbon counter electrode was used in all experiments in 6 mol L\(^{-1}\) KOH electrolyte. CV tests were done on a CHI 650D electrochemical workstation.
Galvanostatic charge/discharge tests were carried out on a Neware Battery Tester (BTS6.0, Neware Technology Company, Guangdong, China).

The capacitance of the electrode (C) was calculated according to the following equation based on CVs or the discharge curves.

\[
C = \frac{Q}{V} = \frac{i \Delta t}{\Delta V_m} \quad (1)
\]

where \( i \) is the sampled current, \( \Delta t \) is a sampling time span, \( \Delta V \) is the total potential deviation of the voltage window, and \( m \) is the mass of the active material examined.

![Fig. S1 XRD patterns of CoB and CoB@Ni(OH)\(_2\).](image)

Fig. S1 XRD patterns of CoB and CoB@Ni(OH)\(_2\).
**Fig. S2** (a) Overall XPS surveys of CoB and CoB@Ni(OH)$_2$; (b) Co 2p; (c) B 1s XPS of CoB and CoB@Ni(OH)$_2$; (d) Ni 2p; and (e) O 1s XPS of CoB@Ni(OH)$_2$. 
Fig. S3 XRD pattern of CoB@Ni(OH)$_2$ with 19.79 wt.% and 27.98 wt.% Ni(OH)$_2$.

Fig. S4 SEM images of CoB@Ni(OH)$_2$ with the different masses of Ni(OH)$_2$; (a): 12.26 wt.%, (b): 19.79 wt.%, (c): 27.98 wt.%.

Fig. S5 N$_2$ isotherms and the pore size distribution (Inset) of CoB and CoB@Ni(OH)$_2$. 
Fig. S6 (a) N$_2$ isotherms; (b) corresponding pore size distribution of CoB and CoB@Ni(OH)$_2$ with 19.79 wt.% Ni(OH)$_2$ (black line) and 27.98 wt.% Ni(OH)$_2$ (red line).

Fig. S7 Comparison of Nyquist plots of the CoB and CoB@Ni(OH)$_2$ (27.98 wt.%) electrodes.

Fig. S8 Schematic of the CoB@Ni(OH)$_2$ hybrid, showing CoB core and Ni(OH)$_2$. 
**Fig. S9** Galvanostatic charge-discharge curves of CoB at different current densities (0.5, 1, 2, 4, and 6 A g\(^{-1}\)).

**Fig. S10** Charge–discharge curves comparison of the first and last 8 cycles of (a) CoB; and (b) CoB@Ni(OH)$_2$; current density: 2 A g\(^{-1}\); electrolyte: 6 mol L\(^{-1}\) KOH.
**Fig. S11** SEM images of CoB@Ni(OH)$_2$ before (a,b) and after (c,d) 2500 continuous charge-discharge cycles at a current density of 2 A g$^{-1}$.

**Fig. S12** Cycling tests of the CoB, CoB@Ni(OH)$_2$ and CoB@Ni(OH)$_2$ without carbon electrodes for 2500 cycles at a current density of 2 A g$^{-1}$. 
**Table S1.** Bulk composition of the as-prepared CoB and a series of CoB@Ni(OH)$_2$ samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moles of NiCl$_2$ precursor (mmol)</th>
<th>Atomic ratio of Co:B:Ni</th>
<th>Mass percentage of Ni(OH)$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoB</td>
<td>---</td>
<td>2.2:1</td>
<td>---</td>
</tr>
<tr>
<td>CoB@Ni(OH)$_2$</td>
<td>0.1</td>
<td>10.43:4.74:1</td>
<td>12.26 wt.%</td>
</tr>
<tr>
<td>CoB@Ni(OH)$_2$</td>
<td>0.14</td>
<td>5.89:2.68:1</td>
<td>19.79 wt.%</td>
</tr>
<tr>
<td>CoB@Ni(OH)$_2$</td>
<td>0.2</td>
<td>3.74:1.70:1</td>
<td>27.98 wt.%</td>
</tr>
<tr>
<td>CoB@Ni(OH)$_2$</td>
<td>0.26</td>
<td>3.88:1.85:1</td>
<td>27.28 wt.%</td>
</tr>
</tbody>
</table>

The bulk elemental compositions of CoB and CoB@Ni(OH)$_2$ samples determined by ICP are listed in Table S1. The mass percentage of Ni(OH)$_2$ in CoB@Ni(OH)$_2$ increased with the increase of the mole of the NiCl$_2$ precursor, and reaches the maximum value of 27.98 wt.% at 0.2 moles of NiCl$_2$. Further increase of NiCl$_2$ reduced the Ni(OH)$_2$ loading content. As described above (see Material Synthesis), the formation of Ni(OH)$_2$ is two-stage, beginning with formation of metallic Co atoms. With the increase of Ni(OH)$_2$ loading, the thickness of the shell covers the available Co atoms thus preventing further reduction of Ni$^{2+}$ to Ni metal.
### Table S2. Comparison of CoB-core@Ni(OH)$_2$–shell with other core-Ni(OH)$_2$-shells reported in the literature.

<table>
<thead>
<tr>
<th>Sample core-shell</th>
<th>Ref.</th>
<th>Specific capacitance (F g$^{-1}$)</th>
<th>Areal capacitance (F cm$^{-2}$)</th>
<th>$^{a}$Current density</th>
<th>$^{b}$Retention(%)/cycling number/$^{c}$current density</th>
<th>Electrolyte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chain-like CoB@Ni(OH) nanosheets</td>
<td>Our work</td>
<td>1293.7</td>
<td>7.76</td>
<td>2 A g$^{-1}$</td>
<td>85%/2500/2 A g$^{-1}$</td>
<td>6 M KOH</td>
</tr>
<tr>
<td>TiN nanowire arrays @gauze-like Ni(OH)$_2$</td>
<td>[1]</td>
<td>2680</td>
<td>---</td>
<td>6 A g$^{-1}$</td>
<td>16%/150/10 A g$^{-1}$</td>
<td>2 M KOH</td>
</tr>
<tr>
<td>SnO$_2$ nanowire arrays @Ni(OH)$_2$ ultrathin nanoflakes/Ni foam</td>
<td>[2]</td>
<td>1553</td>
<td>---</td>
<td>0.5 A g$^{-1}$</td>
<td>---</td>
<td>6 M KOH</td>
</tr>
<tr>
<td>Co$_3$O$_4$ nanowires @Ni(OH)$_2$ /Ni foam</td>
<td>[3]</td>
<td>1330</td>
<td>15.83</td>
<td>2.5 mA cm$^{-2}$</td>
<td>100%/1000/25mA cm$^{-2}$</td>
<td>6 M KOH</td>
</tr>
<tr>
<td>Fe$_2$O$_3$ nanowires @Ni(OH)$_2$ nanosheet/Fe foil</td>
<td>[4]</td>
<td>908</td>
<td>0.97</td>
<td>21.8 A g$^{-1}$</td>
<td>85.7%/5000/54.6 A g$^{-1}$</td>
<td>1 M NaOH</td>
</tr>
<tr>
<td>ZnO nanowires/Ni(OH)$_2$/textile fiber</td>
<td>[5]</td>
<td>3150</td>
<td>---</td>
<td>5 mV s$^{-1}$</td>
<td>98%/5000/20mV s$^{-1}$</td>
<td>1 M LiOH</td>
</tr>
<tr>
<td>Ni$_3$S$_2$ nanorod@Ni(OH)$_2$ nanosheet/graphene</td>
<td>[6]</td>
<td>1037</td>
<td>---</td>
<td>5.1 A g$^{-1}$</td>
<td>99.1%/2000/5.9 A g$^{-1}$</td>
<td>3 M KOH</td>
</tr>
<tr>
<td>NiCo$_2$S$_4$@Ni(OH)$_2$ nanotube arrays/carbon-fabric</td>
<td>[7]</td>
<td>2700</td>
<td>---</td>
<td>$^{d}$1.3 A g$^{-1}$</td>
<td>78%/2000/5.9 A g$^{-1}$</td>
<td>1 M KOH</td>
</tr>
<tr>
<td>NiMoO$_4$@Ni(OH)$_2$ nanorods/Ni foams</td>
<td>[8]</td>
<td>4953</td>
<td>7.43</td>
<td>$^{d}$2.7 A g$^{-1}$</td>
<td>72%/1000/16 A g$^{-1}$</td>
<td>2 M KOH</td>
</tr>
<tr>
<td>ZnCo$_2$O$_4$@Ni(OH)$_2$/Ni foam</td>
<td>[9]</td>
<td>2826</td>
<td>---</td>
<td>2 mA cm$^{-2}$</td>
<td>72%/2000/10mA cm$^{-2}$</td>
<td>3 M KOH</td>
</tr>
<tr>
<td>NiCo$_2$O$_4$@Ni(OH)$_2$/carbon fiber</td>
<td>[10]</td>
<td>2475</td>
<td>6.04</td>
<td>5 mA cm$^{-2}$</td>
<td>73.4%/1000/30mA cm$^{-2}$</td>
<td>2 M KOH</td>
</tr>
</tbody>
</table>

$^{a}$: the specific capacitance and areal capacitance was obtained at the current density.

$^{b}$: after cycling test, the retention of the specific capacitance.

$^{c}$: the cycling test was carried out with the current density.

$^{d}$: the value was calculated based on the data in the literature.
References: