supplementary data

Boosting visible-light-driven catalytic hydrogen evolution via surface

Ti$^{3+}$ and bulk oxygen vacancy in urchin-like hollow black TiO$_2$ decorated

with RuO$_2$ and Pt dual Co-catalyst

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The following is Supplementary data to this article:

The SEM of sectioned RuO$_2$/TiO$_2$/Pt-B (1: 0.6) sample; The EDS-mapping of RuO$_2$/TiO$_2$/Pt-B (1: 0.6) sample; LSV curve; PL curve; BET of the as-prepared samples.

Fig S1: The SEM image of sectioned sample RuO$_2$/TiO$_2$/Pt-B (1: 0.6).
Fig S2: EDS-mapping image of the as-prepared RuO$_2$/TiO$_2$/Pt-B (1: 0.6) sample.

**Ruthenium • Transition Metal**

Primary XPS region: Ru3d  
Overlapping regions: C1s  
Binding energies of common chemical states:

<table>
<thead>
<tr>
<th>Chemical state</th>
<th>Binding energy Ru3d5/2 / eV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ru metal</td>
<td>280.2</td>
</tr>
<tr>
<td>RuO$_2$</td>
<td>280.7</td>
</tr>
</tbody>
</table>

Oxide charge referenced to adventitious C1s peak at 284.8eV.

Fig S3: The Standard binding energy of the Ru metal and RuO$_2$ on the Ru3d.
Fig S4: Linear sweep voltammetry (LSV) of the samples RuO$_2$/TiO$_2$/Pt and RuO$_2$/TiO$_2$/Pt-B (1: 0.6).

Fig S5: Photo-luminescent spectra (PL) of as-prepared samples RuO$_2$/TiO$_2$/Pt and RuO$_2$/TiO$_2$/Pt-B (1: 0.6).
<table>
<thead>
<tr>
<th>Sample</th>
<th>RuO$_2$/TiO$_2$/Pt</th>
<th>RuO$_2$/TiO$_2$/Pt-B (1: 0.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{\text{BET}}$ (m$^2$/g)</td>
<td>140.974</td>
<td>119.243</td>
</tr>
</tbody>
</table>