Mesoporous SnO$_2$ agglomerates with hierarchical structures as an efficient dual-functional material for dye-sensitized solar cells

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Supporting Information (SI) 1

Experimental Details:
(a) **Fabrication of SnO$_2$ by molten salt method:** Tin oxide, (SnO$_2$) mesoporous aggregates were prepared by a Molten Salt Method (MSM) through reacting one mole Tin chloride Tetrahydrate (SnCl$_4$·4H$_2$O, Merck, purity 99%) and 8.8 moles of Lithium Nitrate (LiNO$_3$, Alfa aesar) and 1.2 moles Lithium Chloride (LiCl, Merck) in a Alumina crucible. The mixture was heated in a box furnace (Carbolyte box furnace) at 280°C for 2 hours in air and then washed with water to remove excess Li-salts. Finally, the powder was dried in vacuum oven.

(b) **Fabrication of Dye-Sensitized Solar Cells:** Dye-Sensitized Solar Cells (DSCs) were fabricated by a method of screen-printing. First, FTO plates were cleaned with acetone, ethanol and water, respectively and treated with 50 mM TiCl$_4$ aqueous solution at 70 °C for 30 min. The as-obtained MSM SnO$_2$ aggregates and commercial SnO$_2$ nanoparticles were made into paste with ethyl cellulose and terpinol under certain ratio, and fabricated on FTO substrate FTO by screen-printing on an area of ~ 0.25 cm$^2$. The films were then heated at 450 °C in air for 30 min. The obtained electrodes were immersed into a 1:1 volume mixture of acetonitrile and tert-butanol solution of Ru dye ((Bu$_4$N)$_2$[Ru(Hdcbpy)$_2$(NCS)$_2$] 0.3mM, N719, Solaronix) for 24h to get dye attached. The counter electrodes were prepared by spin-coating H$_2$PtCl$_6$ (50 mM in isopropyl alcohol) on the FTO substrates with following sintering process at 390 °C in air for 30 min. Acetonitrile containing 0.1 M lithium iodide, 0.03 M iodine, 0.5 M 4-tert-butylpyridine, and 0.6 M 1-propyl 2,3- dimethyl imidazolium iodide was used as the electrolyte.

(C) **Characterization:** The as-prepared MSM SnO$_2$ aggregates were characterized by scanning electron microscopy (SEM, JEOL JSM-6701F microscope operated at 10 kV), high-resolution transmission electron microscopy (HRTEM, JEOL 3010 operated at 300 kV), BET surface area (NOVA 4200E Surface Area and Pore Size Analyzer, Quantachrome, USA), powder X-ray diffraction (XRD, Bruker-AXS D8 ADVANCE). And the UV-Vis diffuse reflectance spectra of electrodes were measured with UV-visible spectroscopy (Schimadzu UV-3600 UV-VIS-NIR spectrophotometer). Photocurrent measurements were carried out using a XES-151 S solar simulator (San-Ei, Japan) under AM1.5 G condition.
Supporting Information (SI) 2

TEM image of commercial SnO$_2$ nanoparticles

100 nm
Supporting Information 3

Nitrogen sorption isotherms and pore size distribution of MSM SnO$_2$ agglomerates
**Supporting Information 4**

<table>
<thead>
<tr>
<th>Electrodes</th>
<th>Thickness of the electrode</th>
<th>$J_{sc}$ (mA/cm$^2$)</th>
<th>$V_{oc}$ (V)</th>
<th>FF(%)</th>
<th>η (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSM SnO$_2$</td>
<td>6 µm</td>
<td>7.55±0.1</td>
<td>0.562±0.01</td>
<td>57±0.5</td>
<td>2.41±0.1</td>
</tr>
<tr>
<td>MSM SnO$_2$</td>
<td>8 µm</td>
<td>9.53±0.1</td>
<td>0.562±0.01</td>
<td>57±0.5</td>
<td>3.05±0.1</td>
</tr>
<tr>
<td>MSM SnO$_2$</td>
<td>10 µm</td>
<td>8.22±0.1</td>
<td>0.505±0.015</td>
<td>51±0.5</td>
<td>2.12±0.1</td>
</tr>
<tr>
<td>Commercial SnO$_2$</td>
<td>8 µm</td>
<td>5.23±0.1</td>
<td>0.55±0.015</td>
<td>56±0.5</td>
<td>1.61±0.1</td>
</tr>
<tr>
<td>MSM SnO$_2$+TiCl$_4$</td>
<td>8 µm</td>
<td>13.18±0.1</td>
<td>0.723±0.005</td>
<td>65±0.5</td>
<td>6.23±0.1</td>
</tr>
</tbody>
</table>

I-V parameters of solar cells with different electrodes
Supporting Information 5

![Graph showing UV-vis spectra of dye solutions detached from and SnO₂ electrodes](image)

UV-vis spectra of dye solutions detached from and SnO₂ electrodes
Supporting Information 6

I-V curve of the MSM SnO$_2$ electrode after the TiCl$_4$ post treatment

$V_{oc} = 0.723$

$J_{sc} = 13.18$

$FF = 65.4\%$

$\eta = 6.23\%$