Supporting Information

Facile Preparation of Ultrafine Ti$_4$O$_7$ Nanoparticles-embedded Porous Carbon with High-Areal-Sulfur Loading for Lithium Sulfur Batteries

Ao Chen, Weifang Liu, Hang Hu, Tao Chen, Baolong Ling, Kaiyu Liu*

College of Chemistry and Chemical Engineering, Central South University, Changsha 410083, China

Hunan Provincial Key Laboratory of Chemical Power Source, Changsha 410083, China

* corresponding author, E-mail: kaiyuliu309@163.com

**Fig. S1** Dispersion experiment (a) The mixed solution of silica colloidal solution, TiO$_2$ nanoparticles and SDS. (b) Deionized water with SDS and TiO$_2$ nanoparticles. (c) Silica colloidal solution with TiO$_2$ nanoparticles. (d) Pure deionized water with TiO$_2$ nanoparticles.
Fig. S2. The SEM image of as-prepared PC@Ti$_4$O$_7$. 
Fig. S3. The SEM images of broken large shelled pores.
Fig. S4. The SEM images of four control samples. (a) PC@Ti₄O₇-1, (b-c) PC@Ti₄O₇-2, (e) PC@TiO₂, (f) PC.

Fig. S5. The TEM image of carbon spheres in PC@Ti₄O₇-2.
Fig. S6. The SEM images of as-prepared electrode films. (a) PC@Ti$_4$O$_7$-S electrode, (b) PC@Ti$_4$O$_7$-1-S electrode, (c) PC@Ti$_4$O$_7$-2-S electrode, (d) PC@TiO$_2$-S electrode, (e) PC-S electrode.
**Fig. S7.** The XRD patterns of PC@Ti$_4$O$_7$-1, PC@Ti$_4$O$_7$-2 and PC@TiO$_2$.

**Fig. S8.** $N_2$-sorption isotherms and pore-size distribution of the PC@Ti$_4$O$_7$ and PC@Ti$_4$O$_7$-1 composites.
Fig. S9. Thermogravimetric analysis of $\text{Ti}_4\text{O}_7$ and elemental sulfur.
Fig. S10. The galvanostatic profiles of other four control samples at 1 C.
Fig. S11. (a) The thickness of high sulfur loading electrodes. (b-c) SEM images of thick PC@Ti$_4$O$_7$-S electrodes.

Fig. S12. The galvanostatic charge-discharge curves of PC@Ti$_4$O$_7$-S cathodes with 10.6 and 15.6 mg cm$^{-2}$ sulfur after different cycles.
**Table S1.** EIS test results of PC@Ti$_4$O$_7$-S and PC-S cathode before and after cycles.

<table>
<thead>
<tr>
<th>Cathode</th>
<th>$R_e$ (Ω)</th>
<th>$R_s$ (Ω)</th>
<th>$R_{ct}$ (Ω)</th>
<th>Warburg coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before cycles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC@Ti$_4$O$_7$-S</td>
<td>1.8</td>
<td>31.3</td>
<td>6.3</td>
<td>14.3</td>
</tr>
<tr>
<td>PC-S</td>
<td>2.6</td>
<td>52.7</td>
<td>24.9</td>
<td>22.2</td>
</tr>
<tr>
<td><strong>After cycles</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC@Ti$_4$O$_7$-S</td>
<td>7.9</td>
<td>12.5</td>
<td>2.2</td>
<td>8.0</td>
</tr>
<tr>
<td>PC-S</td>
<td>2.9</td>
<td>25.1</td>
<td>6.4</td>
<td>10.3</td>
</tr>
</tbody>
</table>
Fig. S14. Visualized adsorption of Li$_2$S$_4$ on porous carbon and PC@Ti$_4$O$_7$ with the same amount.
Fig. S15. The long-term cycled PC@Ti$_4$O$_7$-S and PC-S cathodes soaked in mixed DOL/DME solvent.
**Fig. S16.** (a) The SEM images of fresh PC@Ti$_4$O$_7$-S cathode. (b) The cycled PC@Ti$_4$O$_7$-S cathode.