Hybrid Cathode Architectures for Lithium Batteries based on TiS$_2$ and Sulfur

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Supporting information

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Electronic supporting information (ESI) available.
Figure S1. (a) Cycling performance of TiS$_2$, sulfur and TiS$_2$/S$_8$ hybrid electrode at 0.1C. Performance of (b) TiS$_2$ electrode, (c) sulfur electrode (d) TiS$_2$/S$_8$ hybrid cycled at various current rates (0.1C, 0.2C, 0.5C, 0.1C, 1C, 0.1C, 0.2C).

<table>
<thead>
<tr>
<th>Cathode materials</th>
<th>First discharge capacity (mAh/g)$^*$</th>
<th>Capacity after 30 cycles (mAh/g)$^*$</th>
<th>Degradation rate per cycle (%)</th>
<th>Utilization rate(%)$^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% Sulfur cathode</td>
<td>603</td>
<td>189</td>
<td>2.3</td>
<td>36</td>
</tr>
<tr>
<td>50% Sulfur + 30%TiS$_2$ cathode</td>
<td>950</td>
<td>600</td>
<td>1.2</td>
<td>84</td>
</tr>
</tbody>
</table>

Table S1. Comparison of the performance of different cathode materials.

* The capacity is calculated based on the weight of the total active materials.

+ Utilization rate = Experimental Capacity/Theoretical Capacity.
Figure S2. (a) SEM of Ti metal foam. Scale bar= 20 µm. (b) XRD analysis of Ti metal foam.

Figure S3. XRD analysis of the TGA products.
Figure S4. SEM images of (a)TSF5; (b)TSF10; (c) TSF15. Scale bar=20 µm.

Figure S5. (a) Comparison of Raman spectra of 1. Sulfur powder. 2. TiS₂ powder. 3. TSF5. 4. TSF10. 5. TSF15. (b) Zoom-in spectra of sulfur.
Figure S6. XRD analysis of the discharge products of (a) Sulfur electrode. (b) TiS$_2$ electrode. (c) TSF15.

**Method 1**

Method to determine content of Sulfur, TiS$_2$ and Ti metal content using Thermogravimetric analysis (TGA).
1. Ti metal
2. TiS$_2$
3. TSF5
4. TSF10
5. TSF15

Use curve4 as an example. Set the percentage% of sulfur, TiS$_2$ and Ti as x, y, z respectively.

\[ x+y+z=100 \]

\[ y+z=80 \]

\[ y \times 79.866(\text{TiO}_2)/111.997(\text{TiS}_2)+z=59 \]

\[ x=20; \]

\[ y=73; \]

\[ z=7. \]
Method 2

Estamination of the capacity based on the mass of the whole electrode

The areal weight with 4.7mg/cm$^2$ of Al current collector is used here to calculate S wt% in total cathode weight.

For example, in reference 6, sulfur loading is 1.13 mg/cm$^2$, percentage of sulfur in the electrode slurry is 59 wt% and a capacity ~ 1100 mAh/g is obtained in 20$^{th}$ cycle.

Capacity based on the whole electrode =

$$1100 \text{mAh/g} \times \frac{1.13 \text{mg/cm}^2}{21.13 \text{mg/cm}^2} / 0.59 + \frac{4.7 \text{mg/cm}^2}{2} = 181 \text{mAh/g}$$