Nitrogen-Doped Carbon Encapsulated SnO$_2$-SnS/Graphene Sheets with Improved Anodic Performance in Lithium Ion Battery

Fig. S1 SEM images of a) C@SnO$_2$/GN, b) SnO$_2$/GN and c) N-C@SnO$_2$-SnS/GN.

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Fig. S2 TEM images of a) and c) C@SnO$_2$/GN, b) SnO$_2$/GN, and d) HRTEM image of C@SnO$_2$/GN.

Fig. S3 AFM image of SnO$_2$/GN.
Fig. S4 XRD pattern of N-C@SnO$_2$/GN.

Fig. S5 XPS survey spectra of a) N-C@SnO$_2$-SnS/GN and b) N-C@SnO$_2$/GN.
Fig. S6 FTIR spectra of N-C@SnO$_2$-SnS/GN.

Fig. S7 Cyclic voltammogram (CV) curves of N-C@SnO$_2$/GN electrode at a scanning rate of 0.1 mV s$^{-1}$ in the voltage range of 0.01 - 3 V vs. Li$^+$/Li.
Fig. S8 Cycling performance of N-C@SnO$_2$/GN and N-C@SnO$_2$-SnS/GN electrodes in the voltage range of 0.01 - 3 V vs. Li$^+/\text{Li}$. As shown in Fig. S8, the cycling performance of N-C@SnO$_2$/GN electrode was evaluated and compared with N-C@SnO$_2$-SnS/GN. N-C@SnO$_2$-SnS/GN and N-C@SnO$_2$/GN delivered initial discharge capacities of 1970 and 1670 mA h g$^{-1}$ at a current density of 0.1 A g$^{-1}$. After twelve discharge/charge cycles, the corresponding capacities fell to 943 and 828 mA h g$^{-1}$, respectively. The higher specific capacity and better cycling stability of N-C@SnO$_2$-SnS/GN provides forceful confirmation to the cushioning effect of SnS in N-C@SnO$_2$-SnS/GN.

Fig. S9 Specific volumetric capacity vs. cycle number for N-C@SnO$_2$-SnS/GN electrode.

To evaluate the specific volumetric capacity of the sample, we gauged the density of
the electrode material composite.\textsuperscript{S1} The measured electrode density is approximately 0.61 g cm\textsuperscript{-3}, which is close to the values commonly observed in nano-scale materials.\textsuperscript{S2,S3} As is depicted in Fig. S9, the N-C@SnO\textsubscript{2}-SnS/GN delivers initial discharge and charge specific volumetric capacities of 1202 and 796 mA h cm\textsuperscript{-3}, respectively, after 110 cycles, the electrode still retains a volumetric capacity of 734 mA h cm\textsuperscript{-3}. Such performance precedes graphitic anodes (~620 mA h cm\textsuperscript{-3}).\textsuperscript{S4}

Fig. S10 SEM images of N-C@SnO\textsubscript{2}-SnS/GN after cycling.
Fig. S11 SEM images of N-C@SnO$_2$-SnS/GN a) before and d) after cycling; b), e) corresponding elemental mapping images of C; c), f) corresponding elemental mapping images of N.

Fig. S12 a) Nyquist plots of N-C@SnO$_2$-SnS/GN and C@SnO$_2$/GN obtained by applying a sine wave with an amplitude of 5.0 mV over the frequency range 100 kHz to 0.01 Hz; b) Equivalent circuit model of the samples. R$_e$ is the electrolyte resistance and R$_f$ is the resistance of the surface film formed on the electrodes (contact resistance). R$_{ct}$ is charge transfer resistance.
Table S1 Kinetic parameters of C@SnO$_2$/GN and N-C@SnO$_2$-SnS/GN.

<table>
<thead>
<tr>
<th>Samples</th>
<th>C@SnO$_2$/GN</th>
<th>N-C@SnO$_2$-SnS/GN</th>
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<tbody>
<tr>
<td>$R_f$(Ω)</td>
<td>44.64</td>
<td>17.69</td>
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<tr>
<td>$R_{ct}$(Ω)</td>
<td>229</td>
<td>70.34</td>
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References:


