*Supporting Information*

# Ultrastable Li-ion battery anode by encapsulating SnS nanoparticles in sulfur-doping graphene bubble film

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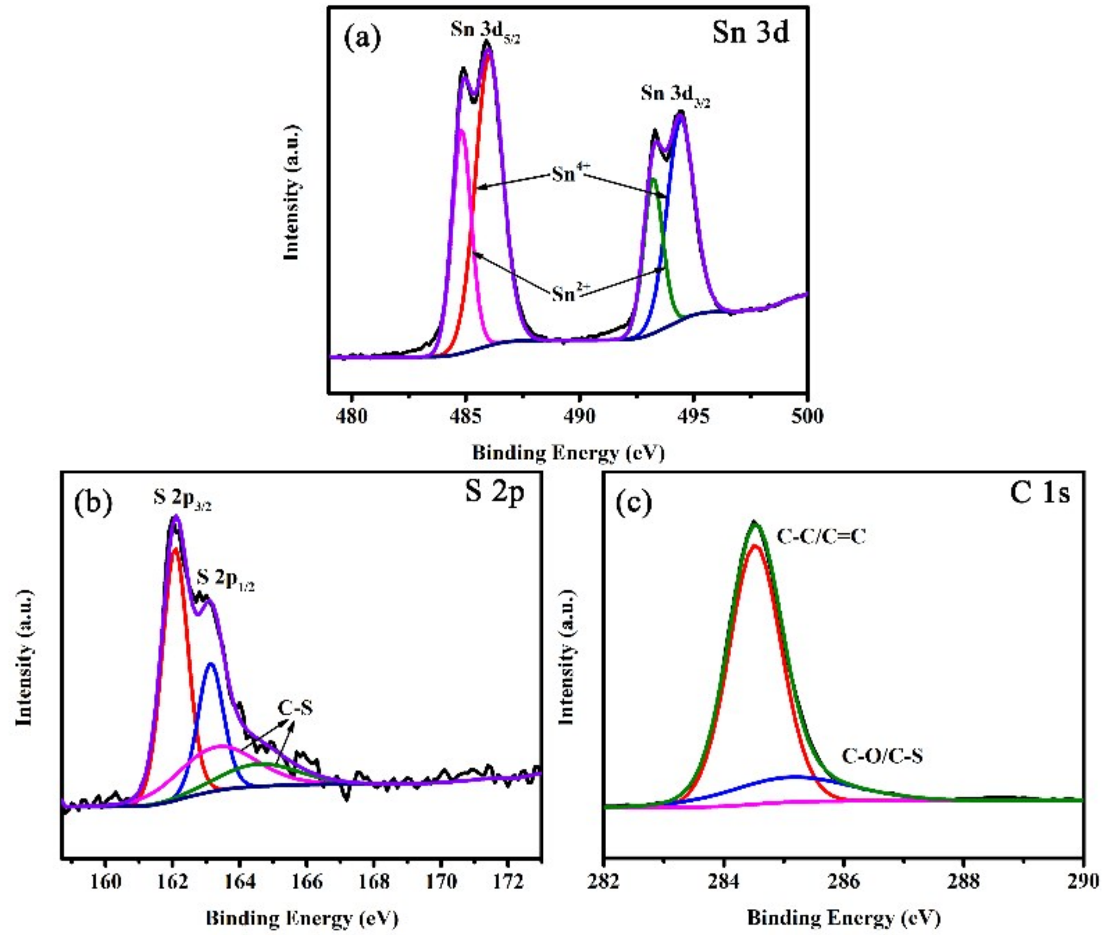


**Figure S1.** High-resolution (a) Sn 3d, (b) S 2p, and (c) C 1s XPS spectra of SnS/G.

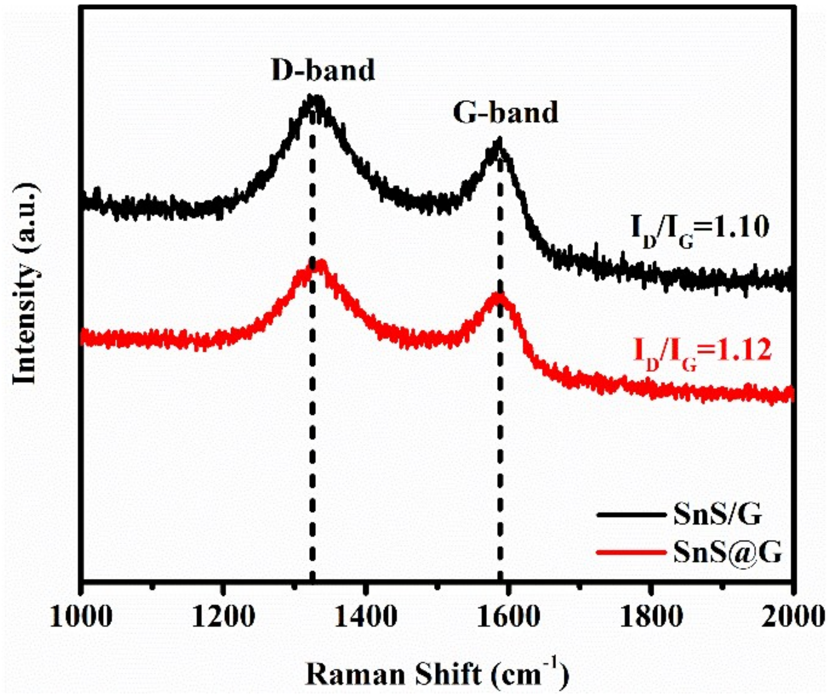


**Figure S2.** Raman spectra of SnS/G and SnS@G composites.

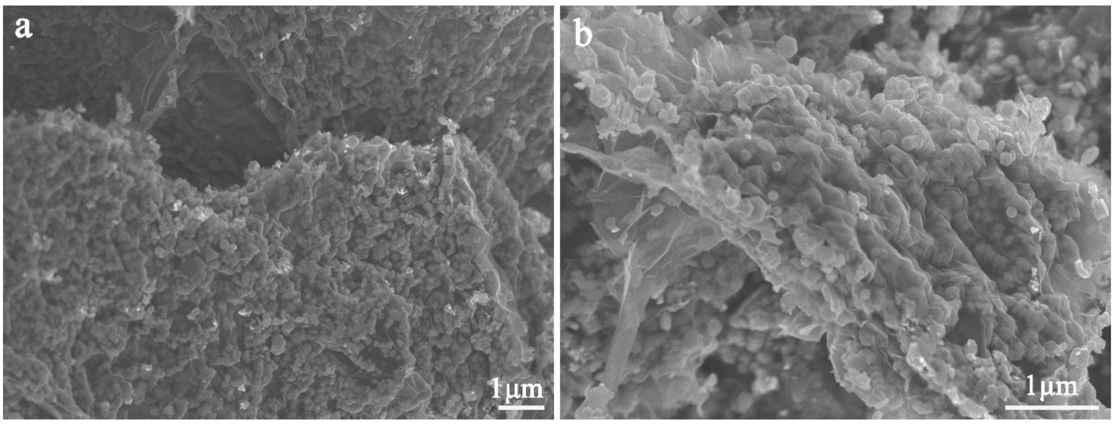


**Figure S3.** SEM images of SnS@G.

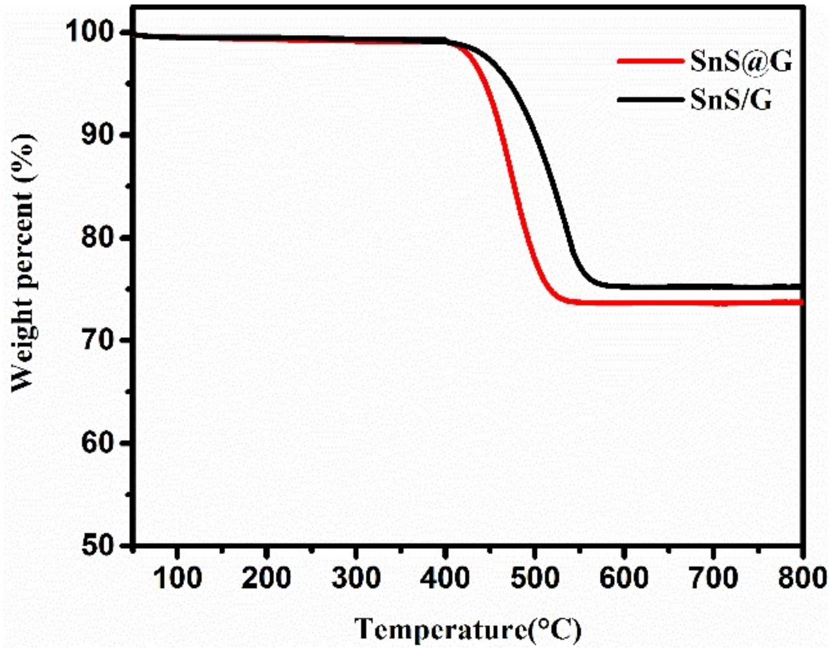


**Figure S4.** TG curves of SnS/G and SnS@G.

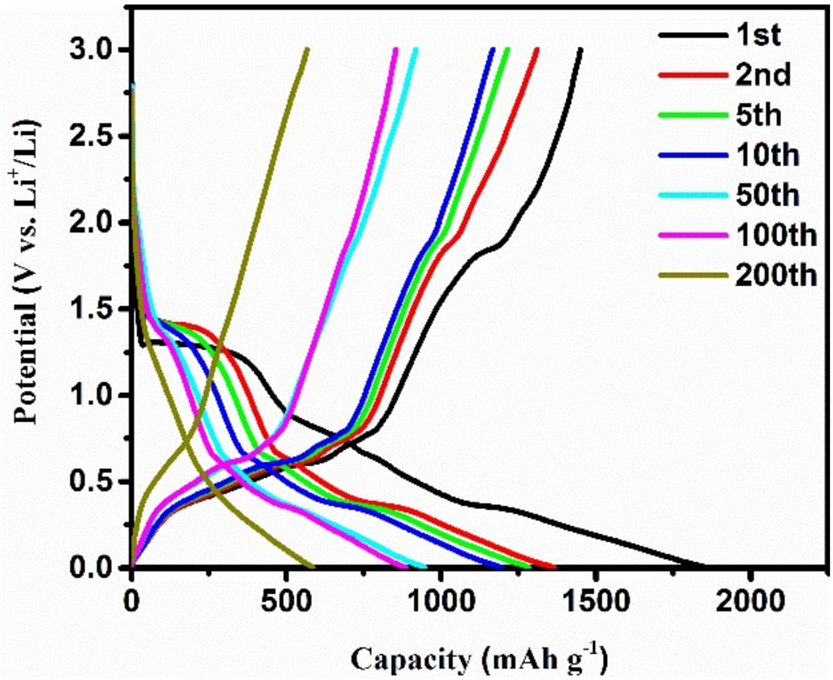


**Figure S5.** Typical discharge/charge curves of SnS/G at a current density of 0.1 A $g^{-1}$.

**Table S1.** Comparison of Li storage performances of SnS@G in this work with those of others reported in the literatures.

| Samples | Initial Coulombic efficiency (%) | Capacity retention after long cycles (mAh $g^{-1}$) | | | Ref. |
|---|---|---|---|---|---|
| | | cycles | current densities (A $g^{-1}$) | Reversed capacity (mAh $g^{-1}$) | |
| SnS@G | 83.2 | 200 | 0.1 A $g^{-1}$ | 1462 mAh $g^{-1}$ | This work |
| SnS/Polypyrrole | 59.4 | 50 | 0.1 A $g^{-1}$ | 1000mAh $g^{-1}$ | [S1] |
| SnS/S-GNS | 81.7 | 100 | 0.1 A $g^{-1}$ | 893.9 mAh $g^{-1}$ | [S2] |
| SnS/C NFs | 70.3 | 500 | 0.2 A $g^{-1}$ | 648 mAh $g^{-1}$ | [S3] |
| SnS/C nanospheres | 80.2 | 50 | 0.1 A $g^{-1}$ | 936 mAh $g^{-1}$ | [S4] |
| Se-doped SnS carbon nanofibers | 72 | 100 | 0.1 A $g^{-1}$ | 693 mAh $g^{-1}$ | [S5] |
| SnS nanoparticles/PDDA-$Ti_3C_2$ nanosheets | 82 | 100 | 0.1 A $g^{-1}$ | 646 mAh $g^{-1}$ | [S6] |
| Three-Dimensional SnS @C | 55 | 100 | 0.1 A $g^{-1}$ | 780 mAh $g^{-1}$ | [S7] |
| C@SnS/SnO2@CNFs | 42 | 200 | 0.5 A $g^{-1}$ | 696 mAh $g^{-1}$ | [S8] |

**Table S2** Kinetic parameters of SnS/G and SnS@G electrodes.

| Sample | | $R_e$ (Ω) | $R_f$ Ω() | $R_{ct}$ (Ω) | $\Delta R_{ct}$ (Ω) | $\sigma_w$ (Ω $s^{-0.5}$) | $D_{Li^+}$ ($cm^2$ $s^{-1}$) |
|---|---|---|---|---|---|---|---|
| **SnS@G** | Before cycle | 2.18 | - | 52.69 | 24.73 | 163.14 | $1.49\times10^{-13}$ |
| | After 1st cycle | 2.48 | 17.52 | 27.96 | | | |
| **SnS/G** | Before cycle | 2.08 | - | 61.72 | 12.36 | 371.36 | $2.89\times10^{-14}$ |
| | After 1st cycle | 2.57 | 22.12 | 49.36 | | | |

The true diffusion coefficient of lithium ion ($D_{Li^+}$) can be calculated from the sloping lines as the following equation.

$$D_{Li^+} = R^2T^2/2A^2n^4F^4C^2{\sigma_w}^2 \quad (1)$$

where $R$ is the gas constant, $T$ is the absolute temperature, $A$ is the contact area between the composite anode and electrolyte (for simplicity, area of the electrode is used here), $n$ is the charge-transfer number, $C$ is the molar concentration of lithium ions in the active material, $F$ represents the Faraday constant, and Warburg coefficient ($\sigma_w$) is determined by $Z_{re}$ and $\omega^{-1/2}$ (ω is the angular frequency). The linear relationship between $Z_{re}$ and $\omega^{-1/2}$ in the low frequency region is shown in Figure 4g, and the data graph is fitted to the Warburg factor $\sigma_w$, and then the $Li^+$ diffusion coefficient ($D_{Li^+}$) is calculated from equation (1). The results show that the $D_{Li^+}$ of SnS@G is calculated to be $1.49\times10^{-13}$ and 5 times to the SnS/G electrode (Table S1), indicating that rapid lithium ion transport kinetics in obtained for thin SEI layer in the graphene bubble film encapsulated SnS composite.

## References


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