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Supporting Information

Robust and stable intercalated graphene encapsulation of tin nanorods for enhanced cycle and capacity performance of the anode material for lithium storage

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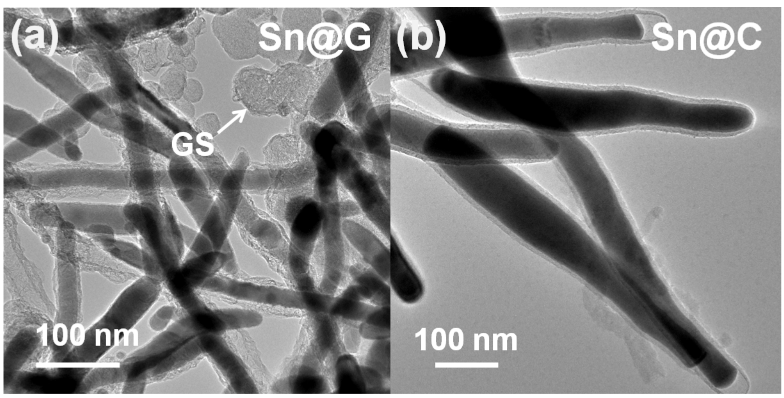

Fig. S1 TEM images of (a) Sn@G synthesized by arc-discharge method and (b) Sn@C by CVD method.

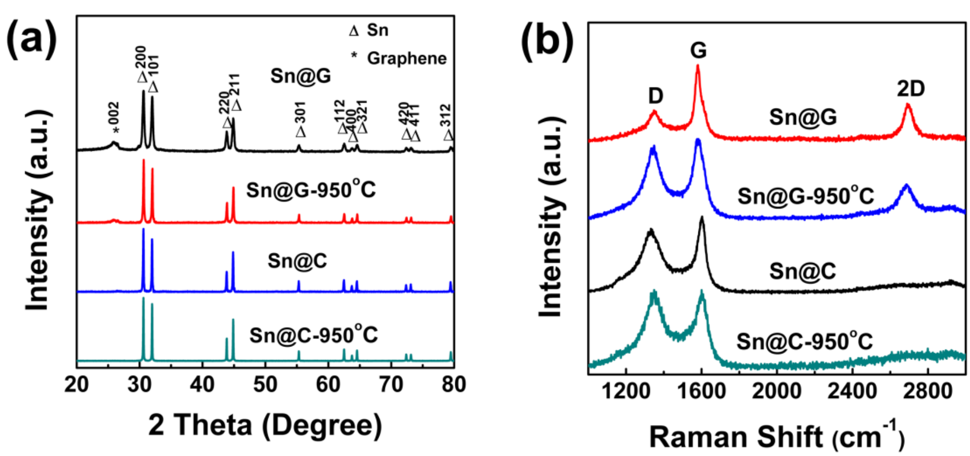

Fig. S2 XRD patterns and Raman spectra of Sn@G, Sn@C, Sn@G-950°C and Sn@C-950°C.

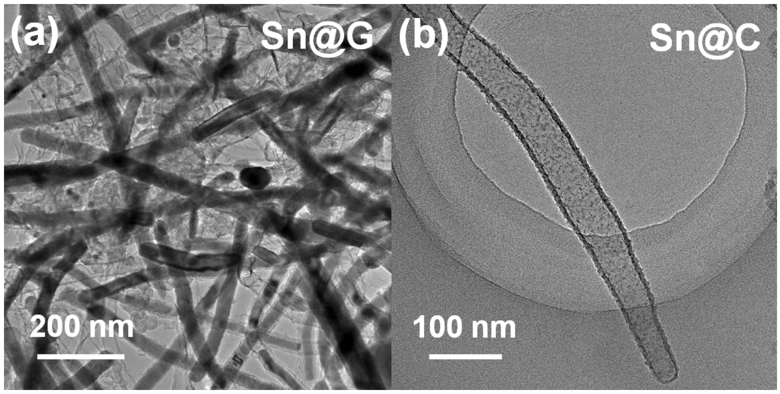

Fig. S3 TEM images of (a) Sn@G and (b) Sn@C after etching by 1 mol L^{-1} hydrochloric acid for 12 h.

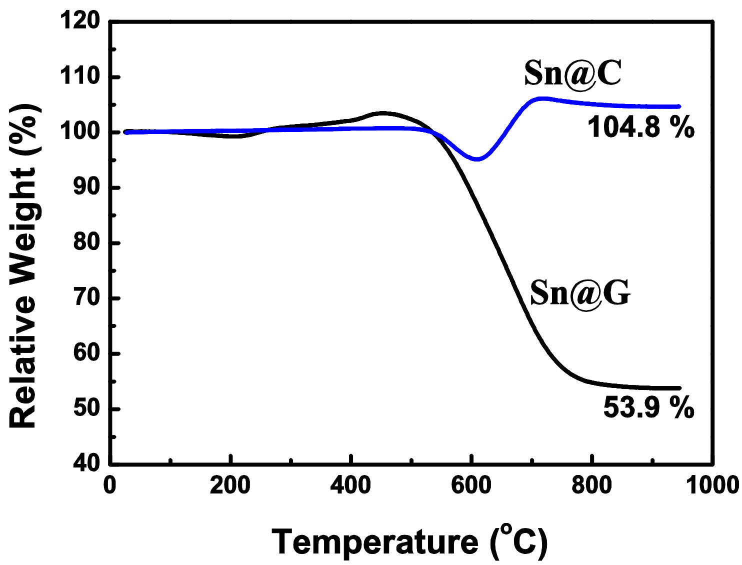

Fig. S4 Thermogravimetric analysis (TGA) of as-prepared Sn@C and Sn@G. The Sn content of Sn@C and Sn@G samples estimated from the thermal analysis are ca. 82.5 wt% and 42.5 wt%, respectively. (Note: Sn was oxidized into SnO_2). The analysis was taken in air with a heating rate of 10 °C min^{-1}.

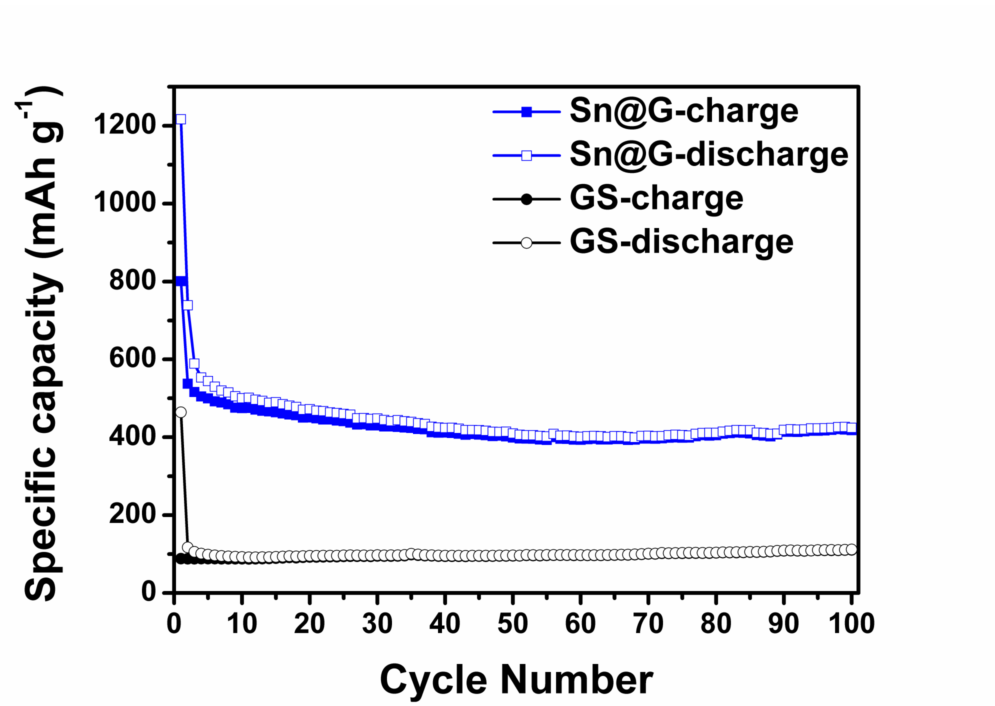

Fig. S5 Cycling performance of graphene sheets (GS) electrodes and specific capacity of Sn@G based on the total weight of the composite at a current density of 200 mA g^{-1} between 0.05 and 3 V.

Demonstration of the volume expansion endurance for Sn@G:

To illuminate the phenomenon, we take one individual Sn@G nanorod for analysis and make the following assumptions:

(1) The mass of the tin core is conservative during the annealing process;

(2) No tin flowing out;

(3) The tube-like graphene shell is completely filled by tin;

The density of metal tin at 25 °C is 7.27 g cm^{-3} and 6.56 g cm^{-3} at 950 °C (calculated according to Ref. 1).[1] Considering the mass of tin is inalterable, we can figure out that the tin volume at 950 °C get increased by 10.7% compared with that at 25 °C according to Eq. 1 and 2.

$$\rho_1 V_1 = \rho_2 V_2 \quad (1)$$

$$\omega = (V_2 - V_1)/V_1 \times 100\% \quad (2)$$

Here, $\rho_{1,2}$, $V_{1,2}$ represents the density and volume of tin at 25 °C and 950 °C separately, ω is the rate of volume change.

According to Hooke's law, the stress σ, the Young's modulus E and the strain ε have the relationship as Eq. 3:

$$\sigma = E\varepsilon \quad (3)$$

Here, Volume strain is taken into consideration. As for the tin core, the strain value is 0.107 ($\varepsilon = 0.107$) at 950 °C. Bulk modulus for solid tin is 58 GPa,[2] but for melting tin it can be smaller. In this case, the stress borne by graphene shell is less than 6.2 GPa according to Eq. 3. Considering that the intrinsic stress of graphene is about 130 GPa,[3] even the strength of graphene encapsulation gets decreased due to the high temperature and its polycrystallinity, it is strong enough to stand the volume change brought by annealing treatment.

References

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3 C. Lee, X. Wei, J. W. Kysar and J. Hone, *Science*, 2008, **321**, 385.

