Supporting Information

In situ chemistry-encapsulated controlled SnS$_2$ nanocrystal composites for durable lithium/sodium-ion batteries

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Experimental Section

The Preparation of C-SnS$_2$@rGO-X (X=0.1, 0.2, 0.4), SnS$_2$@rGO and SnS$_2$.

First, 0.1 g of GO was dissolved into a solution consisting of water (40 mL) and alcohol (20 mL) by ultrasonication of 2 h to obtain the GO dispersing solution. After that, various amounts of glucose (i.e. 0.1, 0.2 and 0.4 g), 0.16 g NaOH, 0.71 g SnCl$_4$·5H$_2$O and 1 g thiourea were added to the above solution, then stirred continued for 12 h. The resulted solution was injected into a 100 mL Teflon autoclave and was kept at 180 °C for 12 h. The C-SnS$_2$@rGO-X (X=0.1, 0.2, 0.4) was washed with deionized water and collected by centrifugation, and then dried at 60 °C. For comparison, the SnS$_2$@rGO was prepared without adding glucose; similarly, SnS$_2$ was prepared without adding rGO and glucose.

Characterization of Materials.

X-ray diffractometer (XRD) was performed on a Rigaku SmartLab X-ray diffractometer with Cu Ka radiation. Raman spectra were obtained with a JY HR-800 Lab Ram confocal Raman microscope. Scanning electron microscopy (SEM, XL 30 ESEM-FEG, FEI Company) and transmission electron microscopy (TEM) were employed to investigate the morphologies of the samples. X-ray photoelectron spectra (XPS) was tested with Mg-Kα excitation (1253.6 eV) in a VGESCALAB MKII spectrometer.

Electrochemical Characterization.

The SnS$_2$-based composites (80%), polyvinylidene fluoride (10%) and acetylene black (10%) were mixed in N-methyl-2-pyrrolidone, and then coated on the Cu foils as
working anodes. The mass loading of SnS$_2$-based composites in electrode was approximately 1.1 mg cm$^{-2}$. 2032-type coin cells were manufactured with 1 M LiPF$_6$ dissolved in dimethyl carbonate and ethylene carbonate (1:1 by volume). The charge/discharge measurements were carried out on a multichannel battery testing system (LAND CT2001A). The cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) tests were measured on an electrochemical workstation (CHI 750 E).

Theoretical Calculation.

We perform first-principle calculations by using Vienna ab initio simulation package with the Perdew-Burke-Ernzerhof-type generalized gradient approximation for the exchange-correlation functional and the projector augmented wave method. All atoms are relaxed until the residual force was less than 0.01 eV/Å. A 3 × 3 × 1 grid of k points and a plane-wave cutoff energy of 400 eV are used for the self-consistent calculations and charge analysis. The d$_2$ vdW interactions are considered through all the calculations.
**Fig. S1** The size of SnS$_2$ NCs under different content of glucose, demonstrating the size of SnS$_2$ NCs is well controlled.

![Figure S1](image1)

**Fig. S2** The Raman spectrum of C-SnS$_2$@rGO-0.2, demonstrating the disordered structure of carbon.

![Figure S2](image2)

**Fig. S3** XPS survey spectra of SnS$_2$@rGO.

![Figure S3](image3)
**Fig. S4** XPS survey spectra of C-SnS$_2$@rGO-0.1 and C-SnS$_2$@rGO-0.4.

**Fig. S5** XPS spectra of C-SnS$_2$@rGO-0.1 and C-SnS$_2$@rGO-0.4: (a, d) Sn 3d, (b, e) C 1s and (c, f) S 2p, revealing that the C-S bonds gradually become stronger with glucose increased in the preparation process.
Fig. S6 FT-IR spectrum of C-SnS$_2$@rGO-0.2, indicating the presence of C-S bonds.

Fig. S7 CV curves of SnS$_2$@rGO, C-SnS$_2$@rGO-0.1 and C-SnS$_2$@rGO-0.4, exhibiting the similar electrochemical processes as C-SnS$_2$@rGO-0.2.
Fig. S8 The cycle performances of (a) C-SnS$_2$@rGO-X (X=0.1, 0.2, 0.4), SnS$_2$@rGO and SnS$_2$, (b) C-SnS$_2$@rGO-X (X=0.1, 0.2, 0.4) electrode.

Fig. S9 The XPS spectra of C-SnS$_2$@rGO-0.2 (a) S 2p, (b) C 1s after 50 cycles at 1 A g$^{-1}$. 
**Fig. S10** SEM images of C-SnS$_2$@rGO-0.2 after 1000 cycles, indicating the stable electrode structure.

**Fig. S11** The TGA curve of C-SnS$_2$@rGO-0.2 at atmosphere from room temperature to 1000 $^\circ$C.

As shown in **Fig. S11**, the sharp weight loss before approximately 650 $^\circ$C is ascribed to the conversion from SnS$_2$ to SnO$_2$ and the burning of carbon. According to the equation (1):

$$ m_{\text{SnS}_2} = \frac{\Delta m}{M_{\text{SnO}_2}} \times M_{\text{SnS}_2} \times 100\% $$

(1)

Where $n$, $M$, $\Delta m$ and $m_{\text{SnS}_2}$ are the quantity of matter, molar mass, the content of SnO$_2$ and SnS$_2$ respectively.

The contents of SnS$_2$ and carbon are calculated to be 78.8% and 21.2%, respectively.
Table S1 The comparison of the electrochemical stability of C-SnS$_2$@rGO-0.2 with other with/without protective layer for SnS$_x$-based materials reported in previous literatures.

<table>
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<th>Samples</th>
<th>Current (A g$^{-1}$)</th>
<th>Reversible Capacity (mAh g$^{-1}$)</th>
<th>Cycle number</th>
<th>Ref.</th>
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