

Supporting Information

Synergistic N-doped carbon encapsulation in porous CoSe₂ nanospheres for enhancing the anode performance of sodium-ion battery

Xiaoyi Hou^{a, b*}, Ying He^a, Dengdeng Ai^a, Jianglong Kang^a, Lijuan Ma^a, Jiatai

Wang^{a, b}

a. College of Physics and Electronic Information Engineering, Qinghai Normal University, Xining 810000, China

b. Qinghai Key Laboratory of Advanced Technology and Application of Environmental Functional Materials, Xining 810016, China

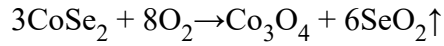
1. Synthesis of pure CoSe₂ microspheres CoSe₂/C

The pure CoSe₂ material was synthesized as follows: 1.5 g of Co(NO₃)₂·6H₂O was dissolved in 50 mL of deionized water, labeled as solution A. 0.6 g of oxalic acid (H₂C₂O₄) was dissolved in 50 mL of deionized water, labeled as solution B. Solution B was slowly added dropwise into solution A, and the mixture was stirred for 30 minutes to complete the precipitation. After centrifugation, the precipitate was dried at 80 °C overnight. The dried product was then calcined at 500 °C for 2 hours under air atmosphere to obtain a precursor. Subsequently, the precursor was selenized in the same manner as described above to obtain pure CoSe₂ material.

The CoSe₂/C composite was synthesized as follows: 12 mmol of Co(NO₃)₂·6H₂O and 27 mmol of glucose were dissolved in a mixed solution of deionized water (20 mL) and ethylene glycol (50 mL). After stirring for about 1 hour, the solution was transferred into an autoclave and placed in an oven at 125 °C for 12 hours. After the reaction, the product was collected by centrifugation, dried, and ground to obtain a precursor. The precursor was then calcined at 500 °C for 2 hours under an Ar atmosphere, followed by selenization to obtain the CoSe₂/C composite.

2. Procedure for analyzing the thermogravimetric (TG) curve

The TG analysis is based on the principle of cobalt element conservation. Under high-temperature calcination in air, CoSe₂ in the composite is completely oxidized to stable Co₃O₄, while the nitrogen-doped carbon, residual elemental selenium, and its oxides are completely removed as gaseous species, thus causing no interference with the residual solid mass. The core oxidation reaction is:



Based on the molar masses $M(\text{CoSe}_2) = 216.85 \text{ g}\cdot\text{mol}^{-1}$, $M(\text{Co}_3\text{O}_4) = 240.79 \text{ g}\cdot\text{mol}^{-1}$, the conversion formula derived from the stoichiometric relationship is:

$$\omega(\text{Co}_3\text{O}_4) = \text{residual mass fraction} \cdot \frac{3M(\text{CoSe}_2)}{M(\text{Co}_3\text{O}_4)}$$

Using the final residual mass fractions measured by TG (29.7% for $\text{CoSe}_2@\text{NC}-500$, 27.6% for $\text{CoSe}_2@\text{NC}-400$, and 11.8% for $\text{CoSe}_2@\text{NC}-300$), the CoSe_2 contents were calculated to be 83.4 wt%, 69.3 wt%, and 66.4 wt%, respectively. Meanwhile, any trace elemental selenium impurity in the samples can be completely sublimed during the heating process, without affecting the reliability of the quantitative results.

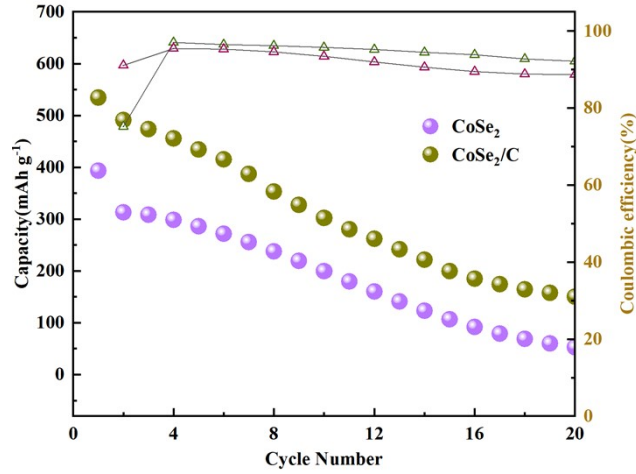


Fig. S1. Cycling performance of the two materials at 0.2 A g⁻¹

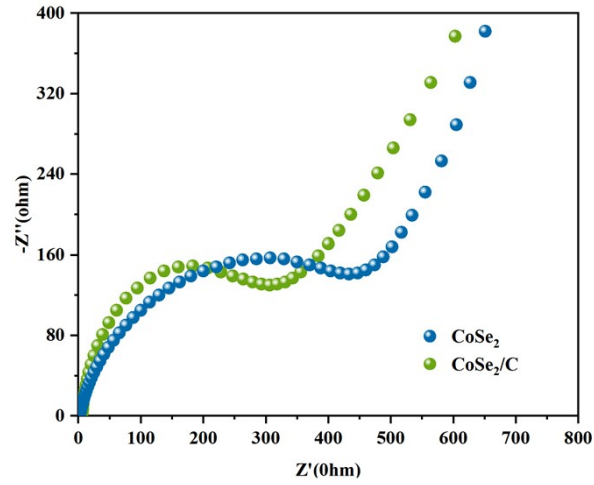


Fig. S2. EIS spectra of the CoSe₂ and CoSe₂/C electrodes.

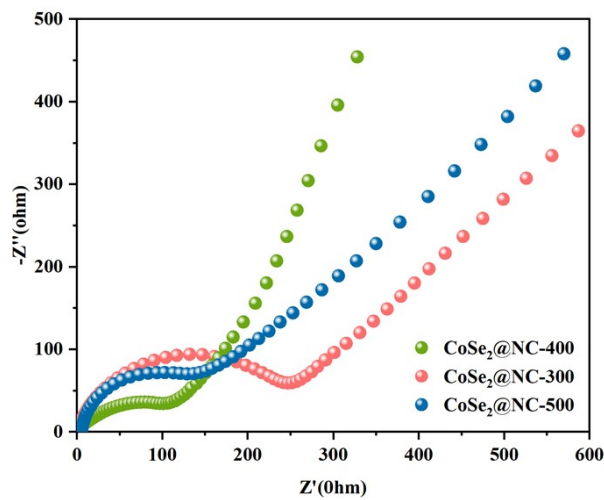


Fig. S3. EIS measurements of CoSe₂@NC-300, CoSe₂@NC-400 and CoSe₂@NC-500 electrodes.

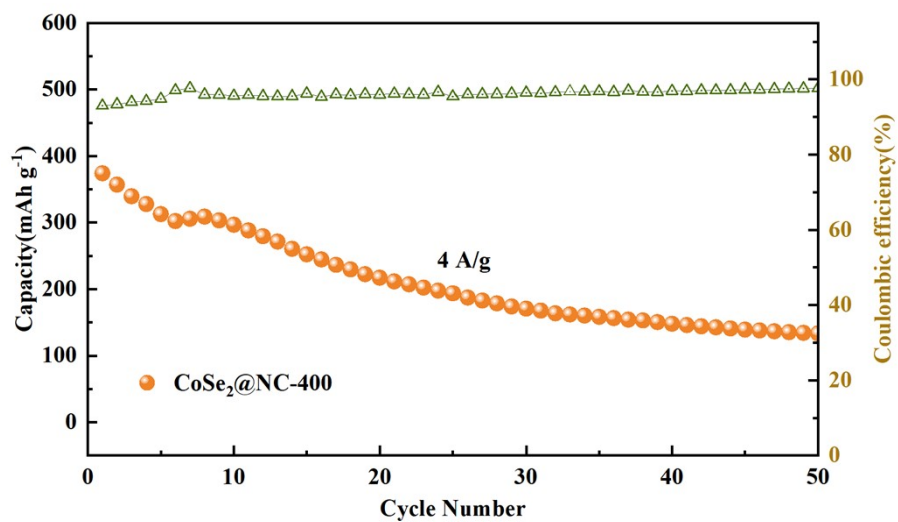


Fig. S4. Cycling performance of the CoSe₂@NC-400 electrodes at 4 A g⁻¹.

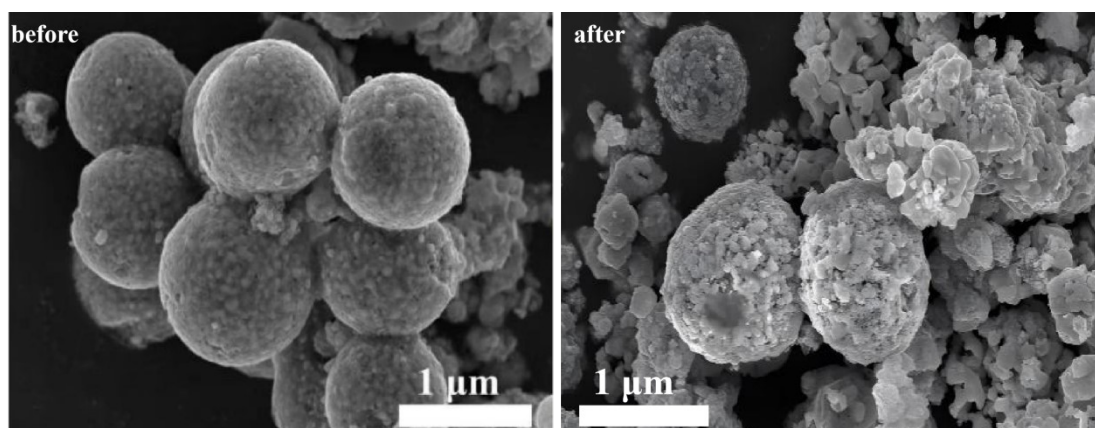


Fig. S5. SEM images of the CoSe₂@NC-400 sample before and after cycling.

Table S1. ICE values of the CoSe₂@NC electrode

	CoSe ₂ @NC-	CoSe ₂ @NC-	CoSe ₂ @NC-
	300	400	500
ICE value	80.5%	87.8%	82.3%

Table S2. Comparison of CoSe₂@NC-400 in this work with other previously reported CoSex.

Materials	Voltage range (V)	Current rate (mA g ⁻¹)	ICE value (%)	References
HS-CoSe ₂ /NC	0.001-3	500	83.7	[1]
N-CoSe ₂ yss	0.01-3	200	83.4	[2]
CoSe/G	0.01-3	100	55.7	[3]
CoSe ₂ /N-CNFs	0.5-3	2000	67.4	[4]
CoSe ₂ @PC	0.001-3	200	84.4	[5]
CoSe ₂ @NC	0.5-3	200	87.8	Our work

References

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