

Supporting Information

Long-life lithium-sulfur batteries with high areal capacity based on coaxial CNTs@TiN-TiO₂ sponge

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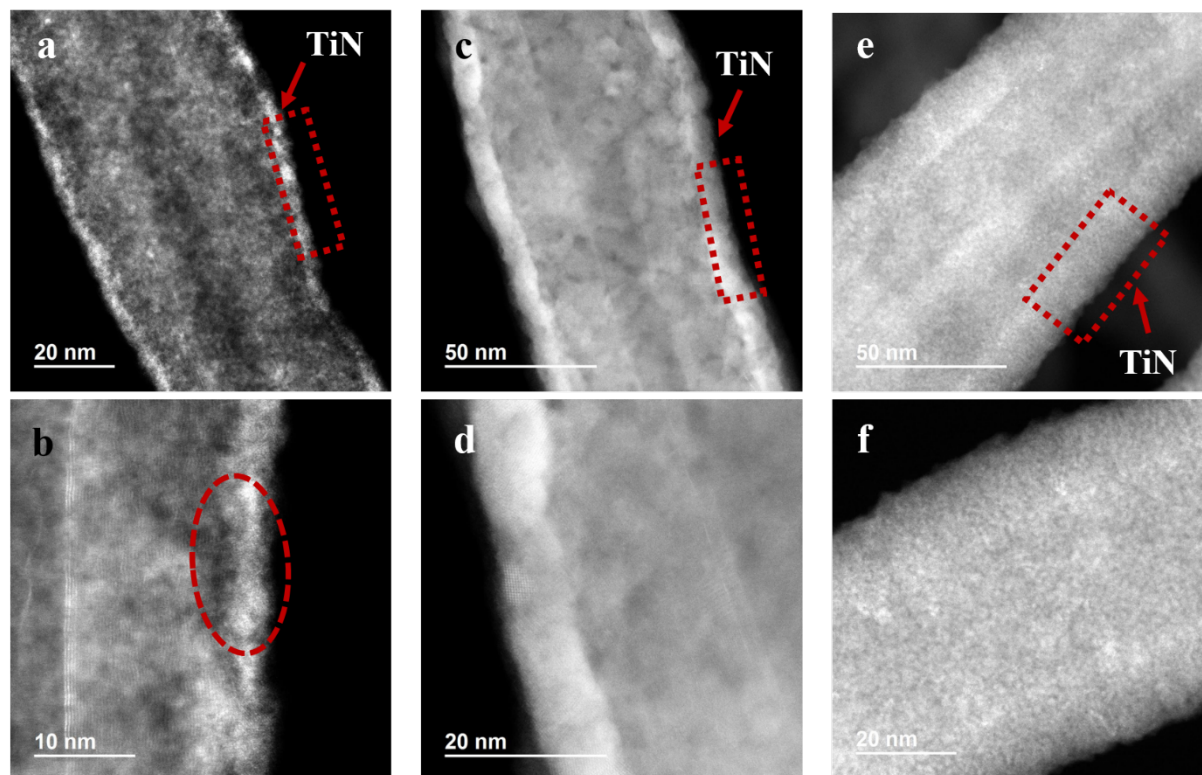


Figure S1. Morphology characterization of CNTs@TiN hybrids. TEM images of (a, b) CNTs@TiN-5, (c, d) CNTs@TiN-10, and (e, f) CNTs@TiN-20. Source data are provided as a Source Data file.

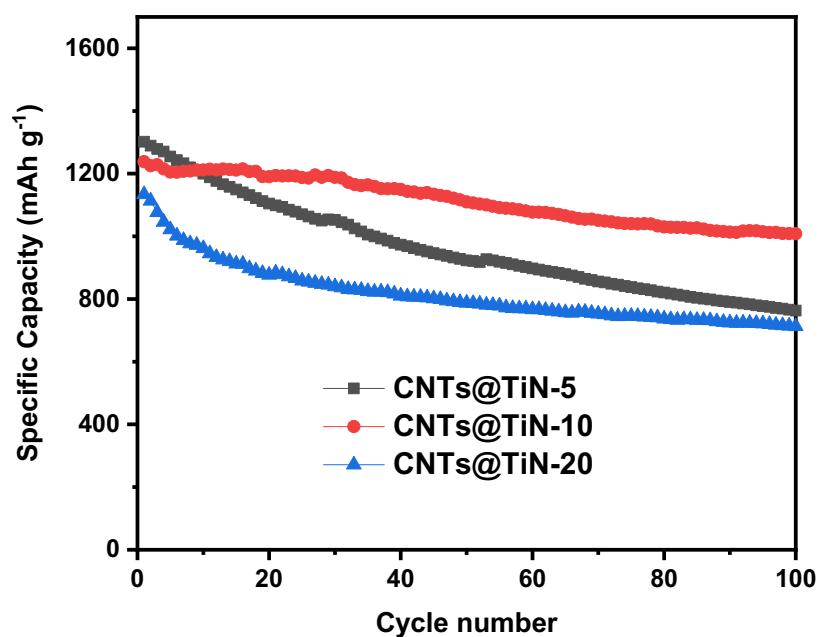


Figure S2. Electrochemical performance of CNTs@TiN hybrids at 0.2 C. Source data are provided as a Source Data file.

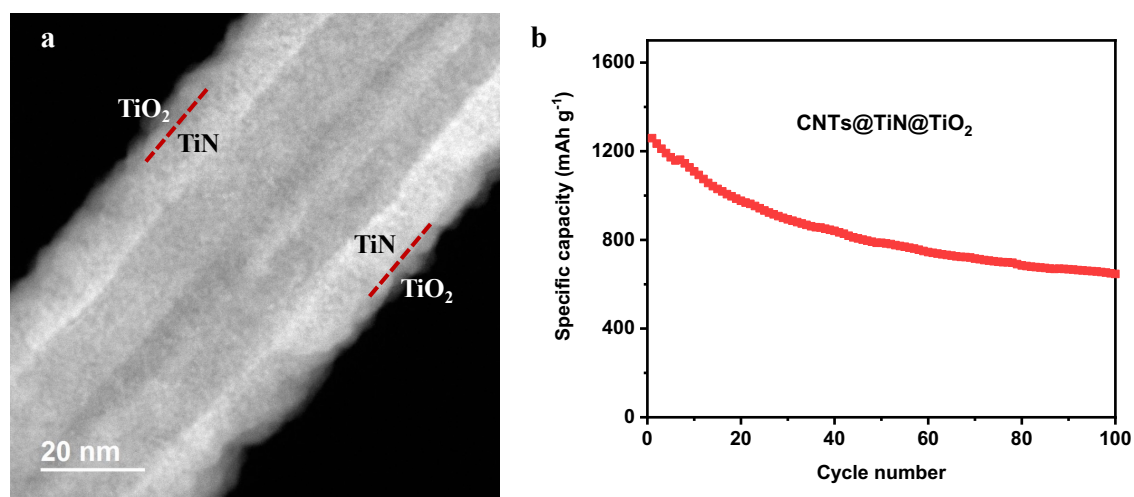


Figure S3. Morphology and electrochemical performance of CNTs@TiN@TiO₂ at 0.2 C. Source data are provided as a Source Data file.

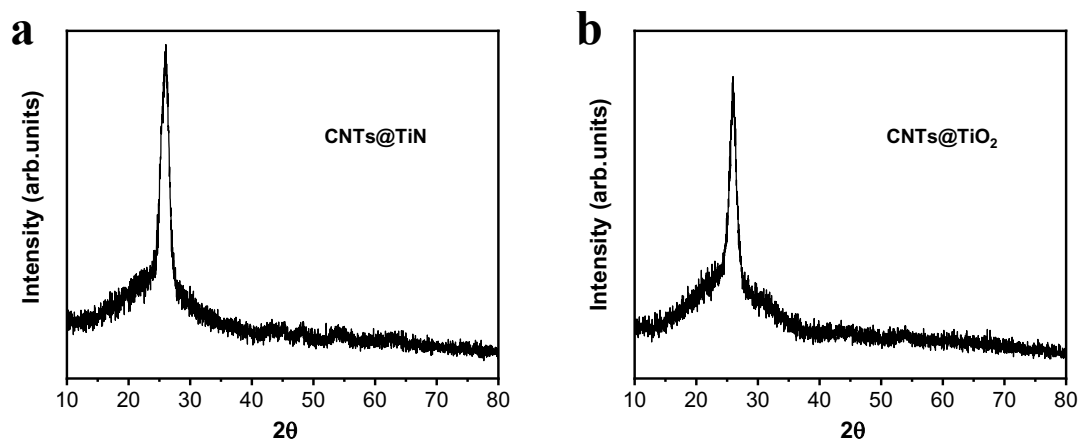


Figure S4. XRD patterns of (a) CNTs@TiN (10 nm) and (b) CNTs@TiO₂ (5 nm). Source data are provided as a Source Data file.

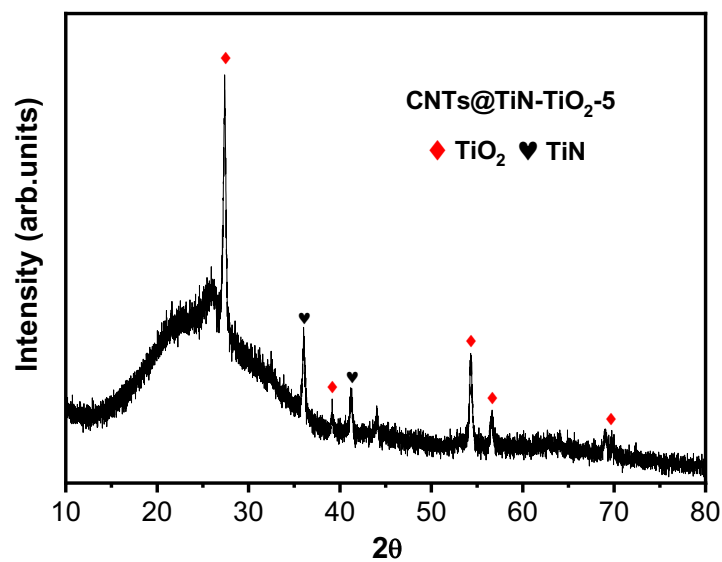


Figure S5. XRD pattern of CNTs@TiN-TiO₂-5. Source data are provided as a Source Data file.

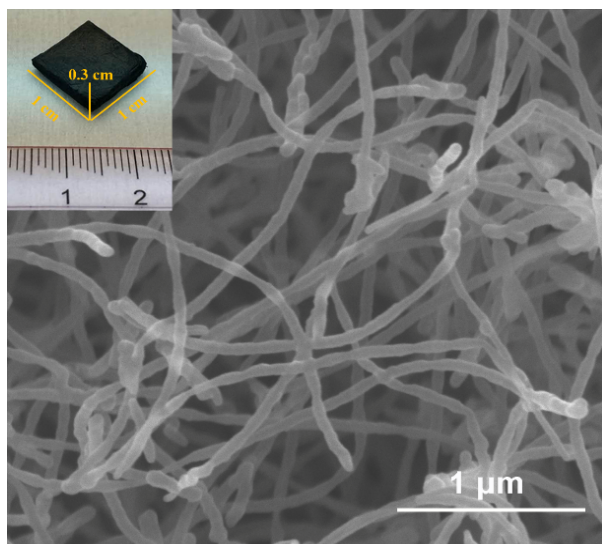


Figure S6. SEM image and photo of CNTs@TiN-TiO₂-5.

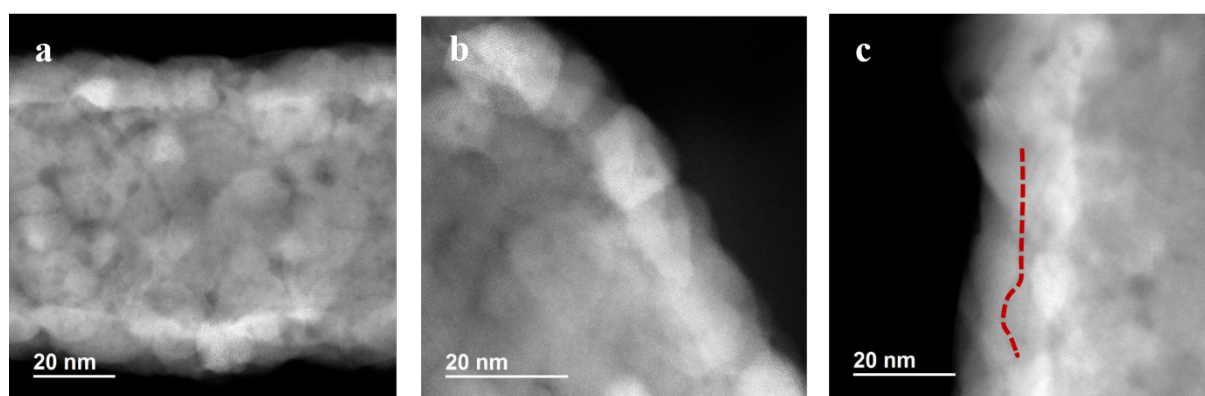


Figure S7. TEM images of (a) CNTs@TiN-TiO₂-2, (b) CNTs@TiN-TiO₂-5 and (c) CNTs@TiN-TiO₂-10. Source data are provided as a Source Data file.

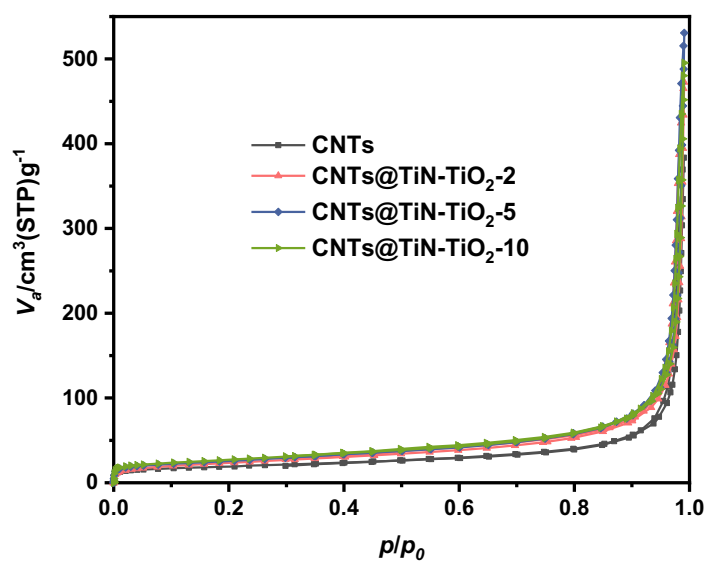


Figure S8. Nitrogen adsorption/desorption isotherms of CNTs, CNTs@TiN-TiO₂-2, CNTs@TiN-TiO₂-5 and CNTs@TiN-TiO₂-10. Source data are provided as a Source Data file.

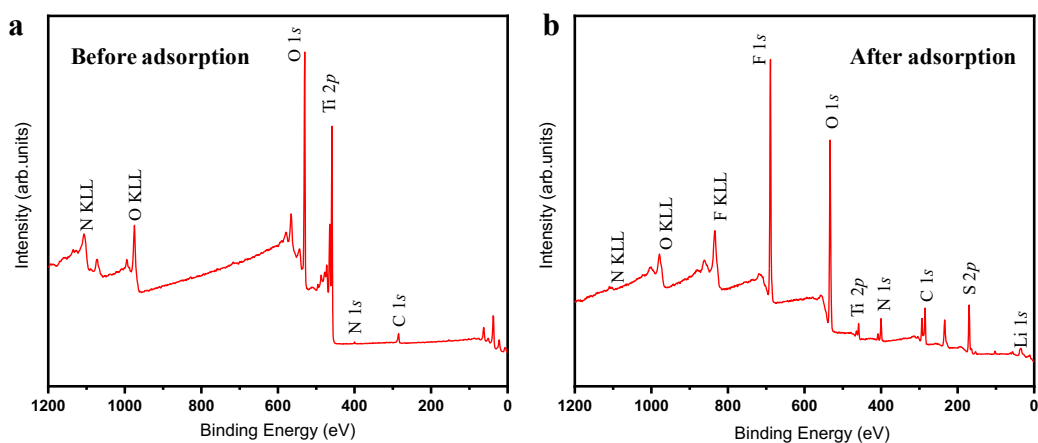


Figure S9. XPS spectra of CNTs@TiN-TiO₂-5 before and after lithium polysulfides adsorption.

Source data are provided as a Source Data file.

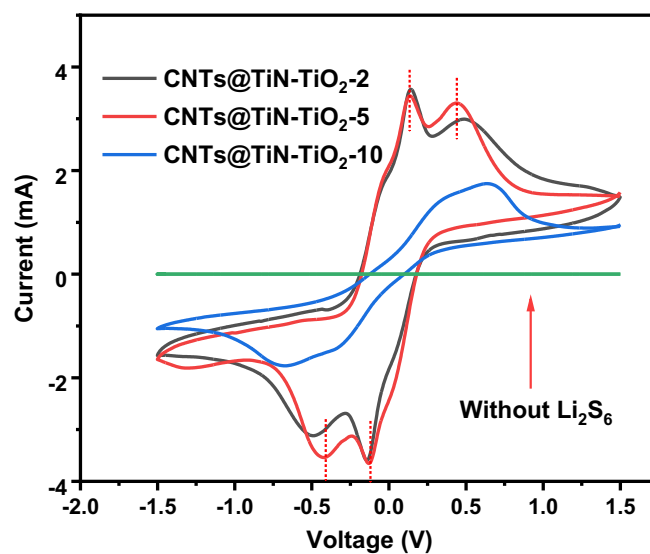


Figure S10. CV curves of CNTs@TiN-TiO₂-2, CNTs@TiN-TiO₂-5 and CNTs@TiN-TiO₂-10 symmetric cells with and without Li₂S₆ at the scan rate of 2 mV s⁻¹. Source data are provided as a Source Data file.

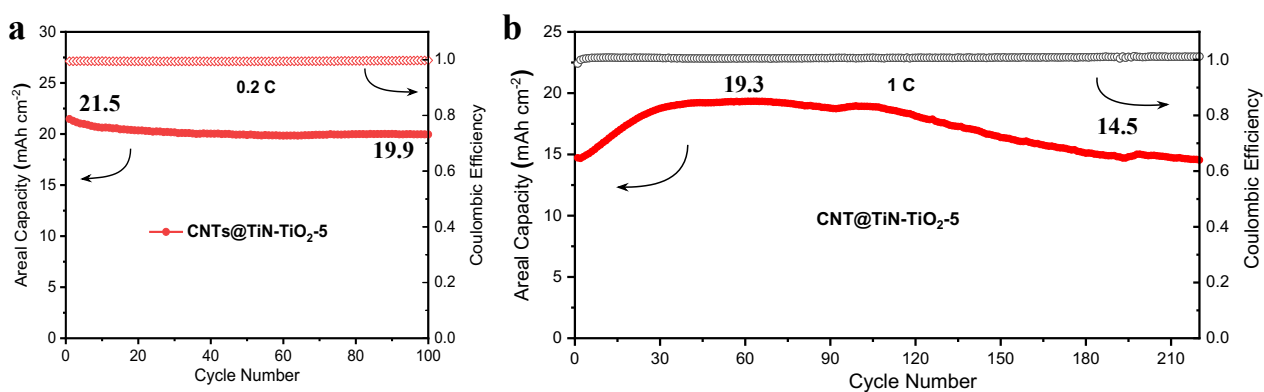


Figure S11. Areal capacity performance of CNTs@TiN@TiO₂-5 at 0.2 C and 1 C. Source data are provided as a Source Data file.

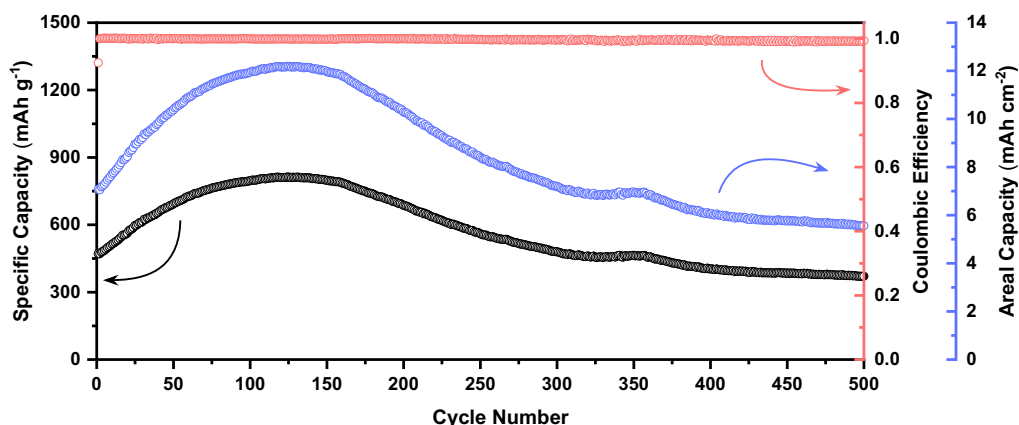


Figure S12. Electrochemical performance of CNTs@TiN@TiO₂-5 at 2 C. Source data are provided as a Source Data file.

Table S1. Electrical conductivity measurement results of CNTs@TiN hybrids by the four-point probe technique.

Sample	ρ_1 (S m ⁻¹)	ρ_2 (S m ⁻¹)	ρ_3 (S m ⁻¹)	Average value (S m ⁻¹)
CNTs@TiN-5	3.23×10^5	3.27×10^5	3.25×10^5	$(3.25 \pm 0.02) \times 10^5$
CNTs@TiN-10	2.87×10^5	2.65×10^5	2.67×10^5	$(2.73 \pm 0.10) \times 10^5$
CNTs@TiN-20	9.87×10^4	9.58×10^4	9.64×10^4	$(9.70 \pm 0.13) \times 10^4$

Table S2. Porosity comparison of CNTs, CNTs@TiN-TiO₂-2, CNTs@TiN-TiO₂-5 and CNTs@TiN-TiO₂-10.

	Specific surface area (m ² g ⁻¹)	Total mesopore volume (cm ³ g ⁻¹)	Average mesopore diameter (nm)
CNTs	67.098	0.5898	35.179
CNTs@TiN-TiO ₂ -2	84.616	0.6901	32.620
CNTs@TiN-TiO ₂ -5	90.980	0.7614	33.474
CNTs@TiN-TiO ₂ -10	96.133	0.7304	30.391

Table S3. Performance comparison of our CNTs@TiN-TiO₂-5 with other recently reported Li-S electrodes with high areal capacity.

Sulfur loading/ (mg cm ⁻²)	Areal capacity (mAh cm ⁻²)		Areal capacity (mAh cm ⁻²)/ n th cycles/C-rate	E/S (μL mg ⁻¹)	Li ₂ S ₆ (M)			Ref.
	Max	100 cycles			Adsorption	Symmetric cells	Li-S cells	
Sulfur-based								
9.8	10.3	6.86	6.3/350/0.2	7.34				7
21.2	23.3	17.04	14.8/150/0.1	3.53				13
10.2	9.26	-	8.18/70/0.2	4.4	0.0048	0.1		26
19.1	19.3	9	9/100/0.1	NA				27
12	13.5	-	10.8/50/0.03	20				28
4	3.60	2.90	2.9/100/0.1	15				32
3.7	3.40	3.25	2.6/500/0.5	10		0.2		33
5.4	4.00	3.00	3/100/0.02	n/a				35
1.5	2.09	1.29	0.82/300/0.2	30				36
Polysulfides-based								
9.6	12	-	9.96/60/0.5	10	0.05		0.52	23
12	11.4	9.73	7.3/200/0.1	6			1	25
57.6	38.57	33.68	28.39/200/0.1	4.2			1.5	29
61.4	57.6	-	42.9/50/0.1	6.8			1	30
5	6.56	4.77	4.13/160/0.2	NA	0.002		0.5	31
18.1	20.00	-	12/70/0.2	5.66			1	34
15	21.5	19.9	19.9/100/0.2	10	0.005	0.5	1.2	Our work
	19.8	14.5	14.5/220/1					