Supplementary Information (SI) for Inorganic Chemistry Frontiers.

Co-nucleated Co doped SnO_2/SnS_2 heterostructures to facilitate diffusion towards high-performance alkali ion storage

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1. Supporting figures

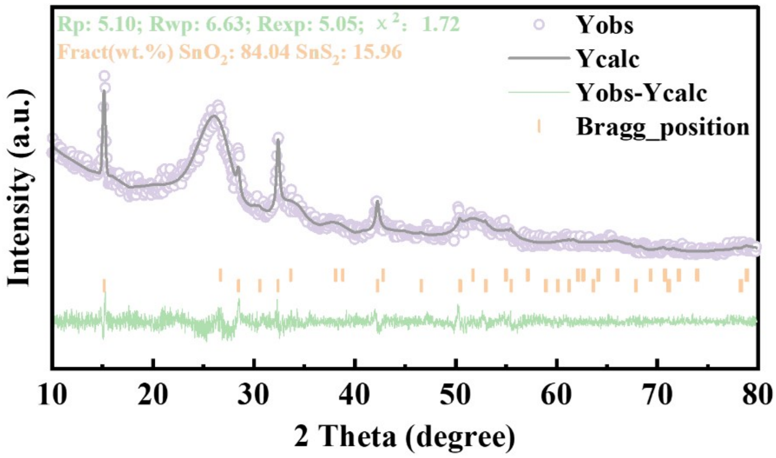


Figure S1. Refined XRD results of $Co_{1/3}$-SnS_2/SnO_2 samples.

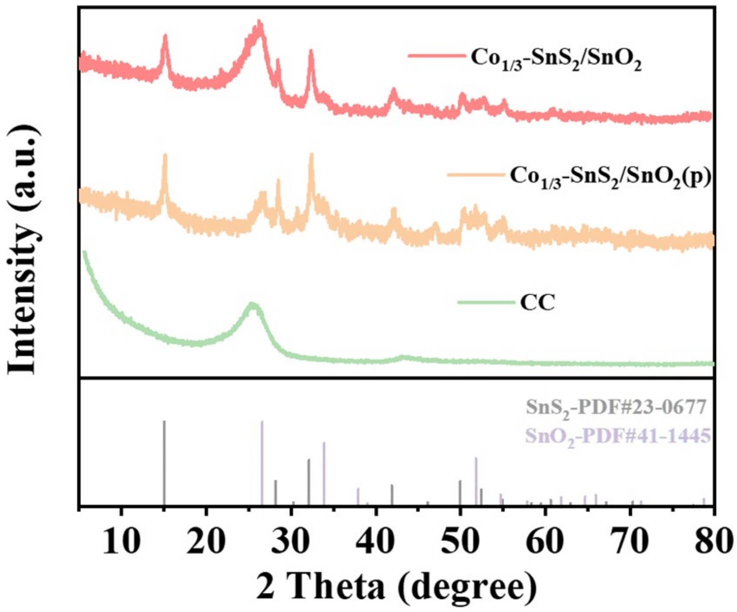
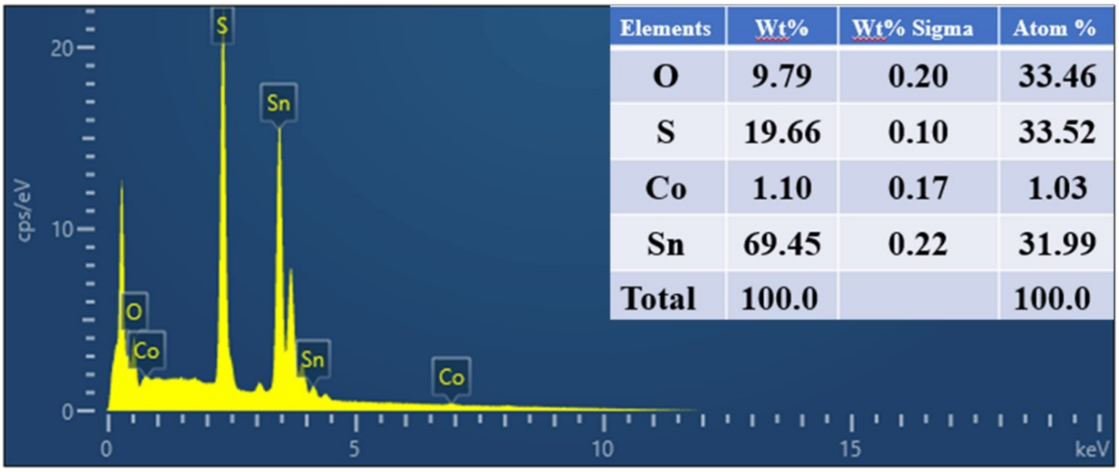


Figure S2. XRD patterns of $Co_{1/3}$-SnS_2/SnO_2, $Co_{1/3}$-SnS_2/SnO_2(p) and blank carbon cloth.



Elements	Wt%	Wt% Sigma	Atom %
O	9.79	0.20	33.46
S	19.66	0.10	33.52
Co	1.10	0.17	1.03
Sn	69.45	0.22	31.99
Total	100.0		100.0

Figure S3. Content of each element in the $Co_{1/3}$-SnS_2/SnO_2 material.

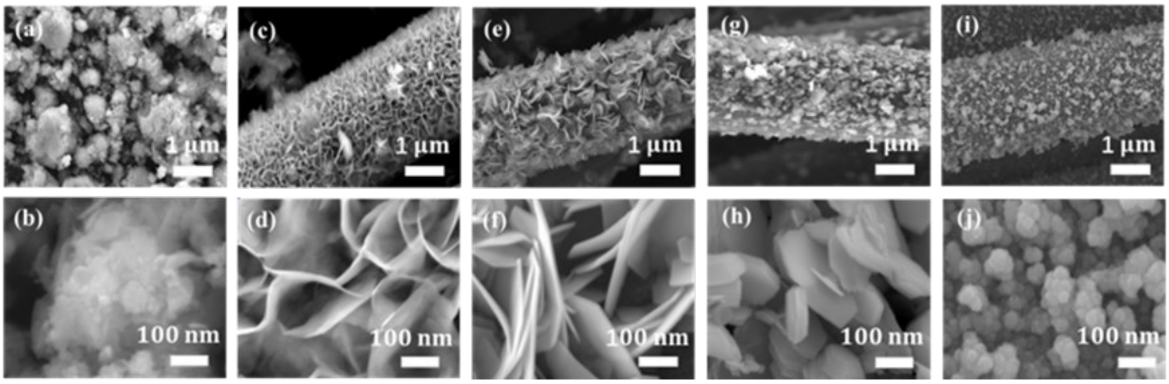


Figure S4. SEM images of (a-b) $Co_{1/3}$-SnS_2/SnO_2(p); (c-d) $Co_{1/3}$-SnS_2/SnO_2;(e-f) SnS_2/SnO_2; (g-h) $Co_{1/3}$-SnS_2; (i-j) $Co_{1/3}$-SnO_2.

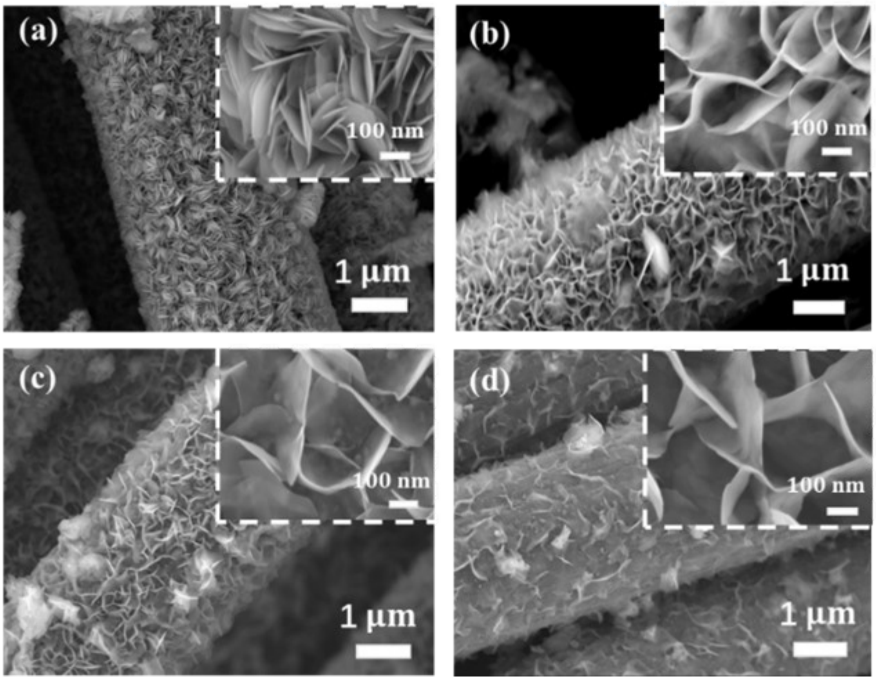


Figure S5. SEM images of (a) $Co_{1/2}$-SnS_2/SnO_2; (b) $Co_{1/3}$-SnS_2/SnO_2; (c) $Co_{1/4}$-SnS_2/SnO_2; (d) $Co_{1/5}$-SnS_2/SnO_2.

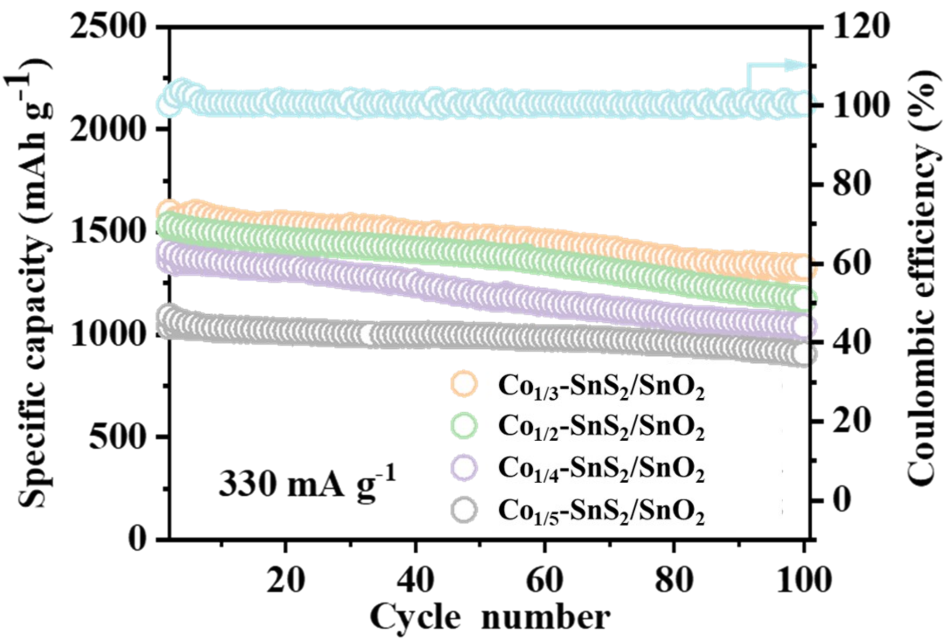


Figure S6. The cycling performance of LIBs using the different $Co_{1/x}$-SnS_2/SnO_2 anodes obtained at different ratio of the Co^{2+}.

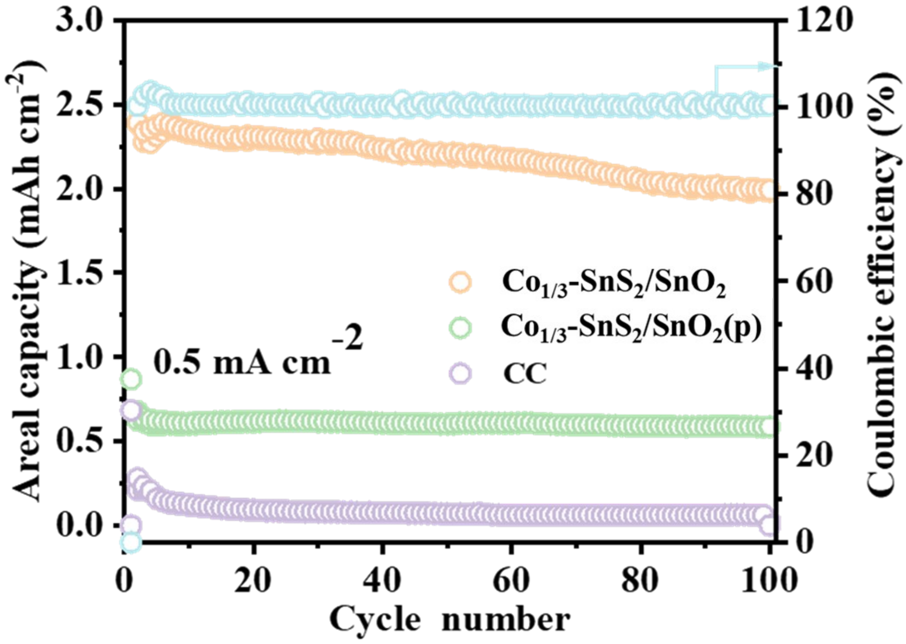


Figure S7. The cycling performance of LIBs using the $Co_{1/3}$-SnS_2/SnO_2, $Co_{1/3}$-SnS_2/SnO_2(p) and CC as anodes.

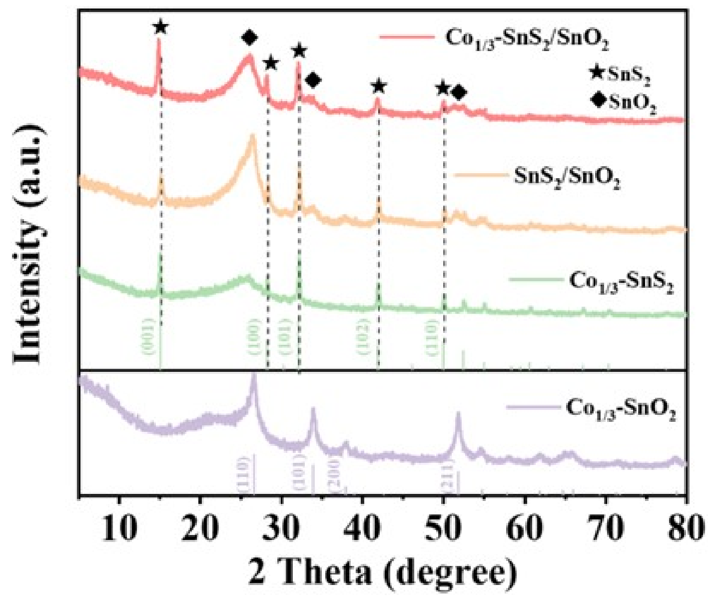


Figure S8. XRD patterns of the comparison samples (SnS_2/SnO_2, $Co_{1/3}$-SnO_2 and $Co_{1/3}$-SnS_2)

Table S1. Comparison of the performance of this material in lithium-ion batteries with SnS_2 and SnO_2 materials reported in other studies.

Sample	Capacity（mAh g^{-1}）	Capacity retention	Ref.
SnS_2@RGO	1800（0.1 A g^{-1}）	52.3 %（100 cycle）	[19]
C@SnS_2	1200（0.1 A g^{-1}）	55 %（100 cycle）	[29]
SnS_2-CNT-CC	1500（0.645 A g^{-1}）	83 %（100 cycle）	[32]
SnS_2/SnO_2/C	1050（0.1 A g^{-1}）	67.8 %（100 cycle）	[33]
SnO_2@N-CNF	754（1 A g^{-1}）	100 %（300 cycle）	[34]
SnO_2@SnS_2	962（0.1 A g^{-1}）	56.9 %（100 cycle）	[35]
$Co_{1/3}$-SnS_2/SnO_2	1518（0.33 A g^{-1}）	81 %（100 cycle）	**This work**

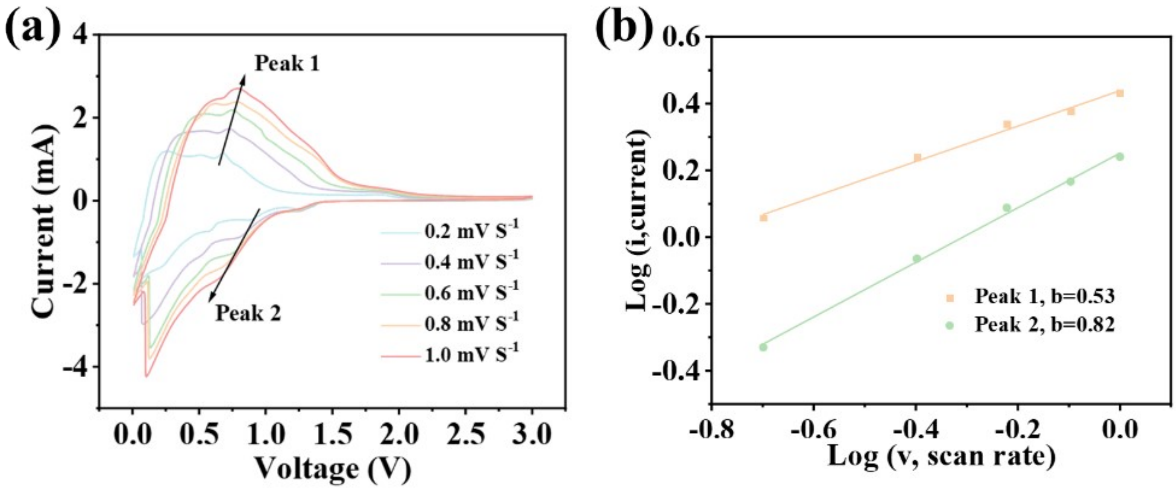


Figure S9. (a) The CV curves at different rate of the LIBs using the $Co_{1/3}$-SnS_2/SnO_2 anodes; (b) Plots of log(i) against log(v) at various peak currents.

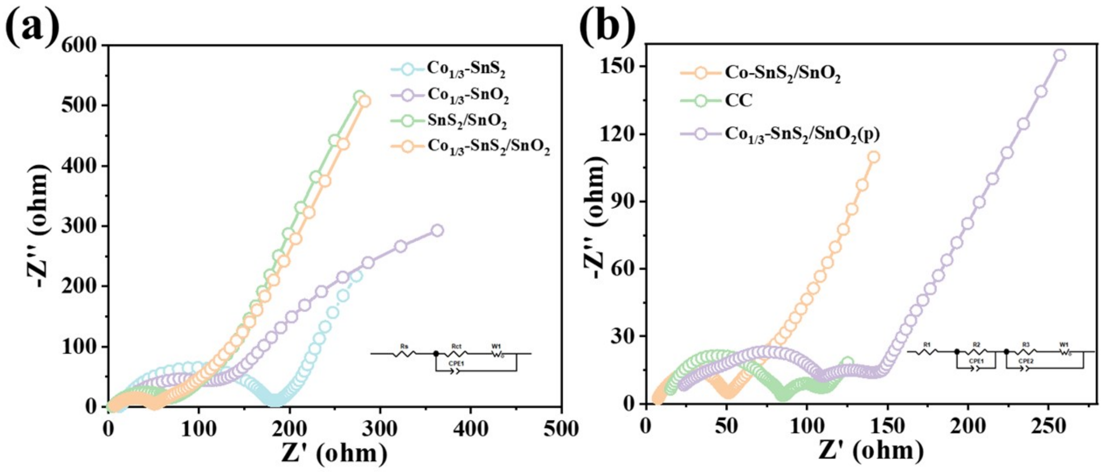


Figure S10. The EIS curves of LIBs with (a) Co$_{1/3}$-SnS$_2$/SnO$_2$, SnS$_2$/SnO$_2$, Co$_{1/3}$-SnO$_2$ and Co$_{1/3}$-SnS$_2$ as anodes; (b) Co$_{1/3}$-SnS$_2$/SnO$_2$, Co$_{1/3}$-SnS$_2$/SnO$_2$(p) and blank carbon cloth as anodes;

Table S2. Fitted EIS data and dynamic parameters of different materials in LIBs.

Sample	R_s（Ω）	R_{ct}（Ω）
Co$_{1/3}$-SnS$_2$	13.22	170.2
Co$_{1/3}$-SnO$_2$	10.38	156.8
SnS$_2$/SnO$_2$	4.672	75.72
CC	10.44	73.57
Co$_{1/3}$-SnS$_2$/SnO$_2$(p)	12.57	121.3
Co$_{1/3}$-SnS$_2$/SnO$_2$	6.242	46.8

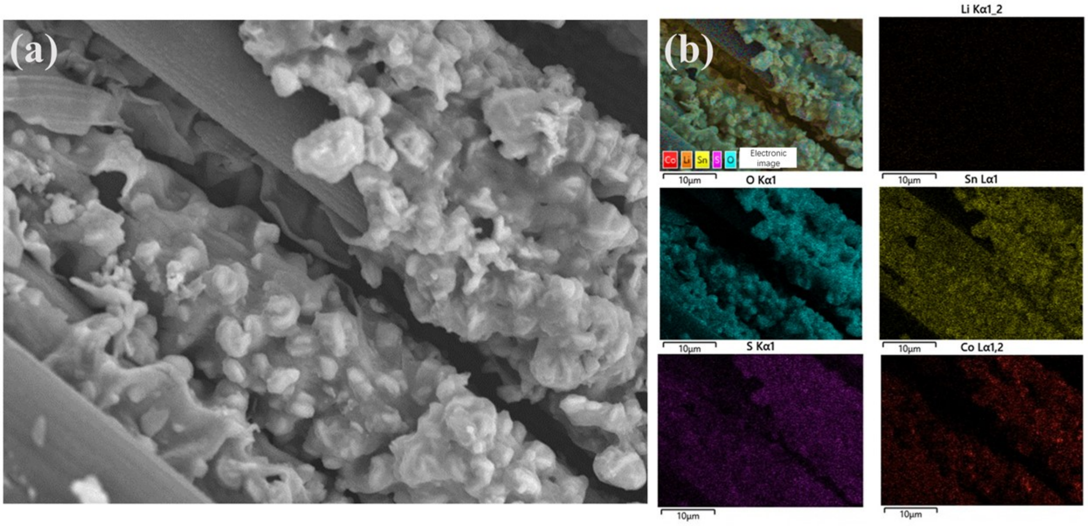


Figure S11. (a) SEM image and (b) EDS of $Co_{1/3}$-SnS_2/SnO_2 anode removed in LIB after 50 cycles at 300 mA g^{-1}.

Figure S12. LEDs light up with LIBs using $Co_{1/3}$-SnS_2/SnO_2 anodes

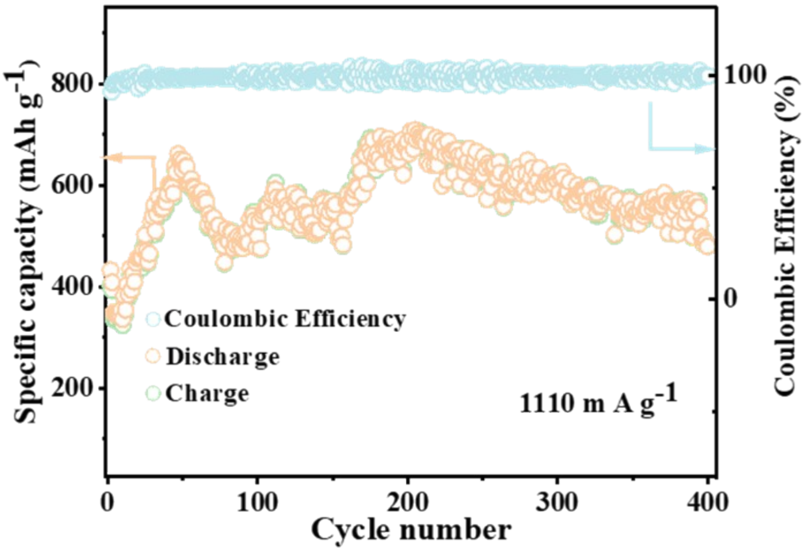


Figure S13. The cycling performance of SIBs using the $Co_{1/3}$-SnS_2/SnO_2 anodes at a current density of 1110 mA g^{-1}.

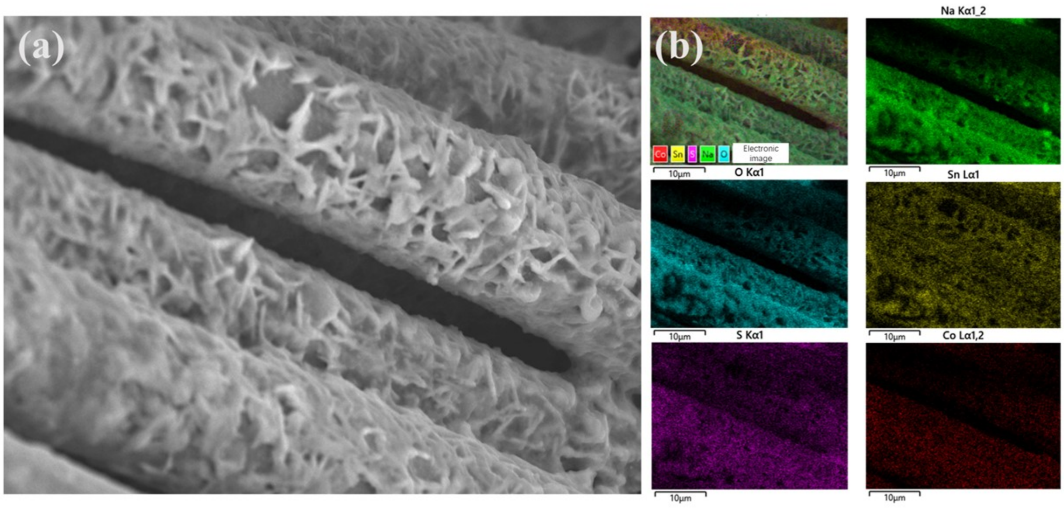


Figure S14. (a) SEM image and (b) EDS of anode removed in SIB after 70 cycles at 300 mA g^{-1}.

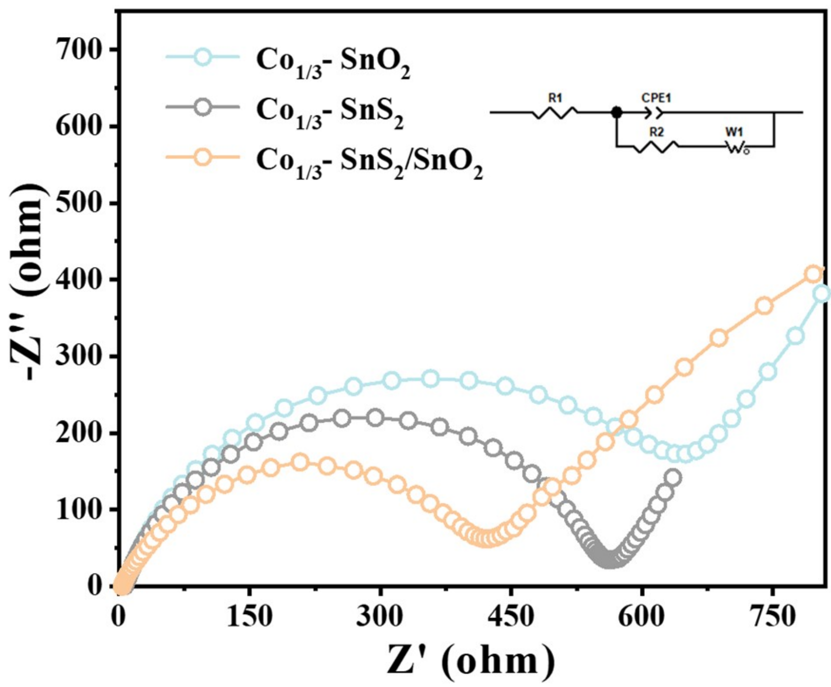


Figure S15. The EIS curves of SIBs with $Co_{1/3}$-SnS_2/SnO_2, $Co_{1/3}$-SnS_2 and $Co_{1/3}$-SnO_2 as anodes;

Table S3. Fitted EIS data and dynamic parameters of different materials in SIBs.

Sample	R_s（Ω）	R_{ct}（Ω）
$Co_{1/3}$-SnS_2	6.649	562.4
$Co_{1/3}$-SnO_2	5.968	734.5
$Co_{1/3}$-SnS_2/SnO_2	3.975	434.7

2.Calculation of ion diffusion coefficient (D_{Li} and D_{Na})

The GITT data was obtained at the 2nd cycle on a LAND constant current charging and discharging system. The ion diffusion coefficient reflecting the dynamic behavior of the electrodes can be calculated based on the following equation:

$$D = \frac{4}{\pi\tau}\left(\frac{m_B v_m}{M_B S}\right)^2\left(\frac{\Delta E_s}{\Delta E_\tau}\right)^2 (\tau \ll \frac{L^2}{D}) \tag{S1}$$

Where D is the ion diffusion coefficient ($cm^2\ s^{-1}$), τ is the constant current pulse time (s), m_B is the quality of the active material (g), v_m is the molar volume of active material ($cm^3\ mol^{-1}$), M_B is relative molecular mass ($g\ mol^{-1}$) of active material, respectively, S is the area where the electrode is in contact with the electrolyte (cm^2), ΔE_S represents the steady-state voltage change by the current pulse and ΔE_τ is the potential change (V) during the constant current pulse.