Supplementary Information for:

Electrochemical Performance of MoS_2, Sb_2S_3, and SnS Anodes in Sodium-Ion Batteries Using a Conductive Polypyrrole-Carbon Black Composite and a Sustainable Binder LBG

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Table S1 Comparison of conductive polymer-based composites used in Na-ion battery electrodes[23-27]

Parameter	PPyCB (this work)	PEDOT-based composites	PANI-based composites
Typical electronic conductivity	~10^{-1} – 10^{0} S·cm^{-1} (CB-enhanced)	~10^{-2} – 10^{-1} S·cm^{-1}	~10^{-2} – 10^{-1} S·cm^{-1}
Structural stability during cycling	Good (stable network, low R_CT increase)	Moderate (PEDOT:PSS swelling, degradation)	Limited (fragile at low/high potentials)
Compatibility with aqueous binders	High	Moderate	Low–Moderate
Reported Na-ion capacity retention	22–23% after 100 cycles (SnS/MoS_2)	~10–20% (literature values vary)	Often below 15%
SEI behavior and interfacial uniformity	Uniform SEI (confirmed by EDS)	Often unstable SEI growth	Susceptible to parasitic reactions
Processing environment	Water-based, pH-neutral	Typically requires acidic or surfactant system	Acidic, less eco-friendly
Mechanical flexibility and film-forming	Good	Moderate	Brittle at high loadings

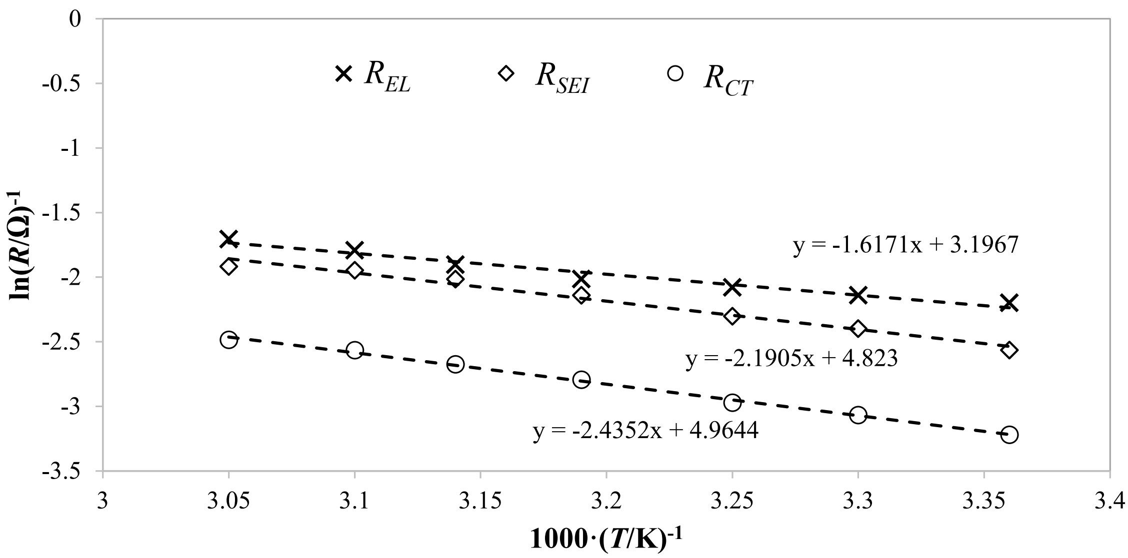

Fig. S1 Arrhenius plot of the half-cell with SnS anode

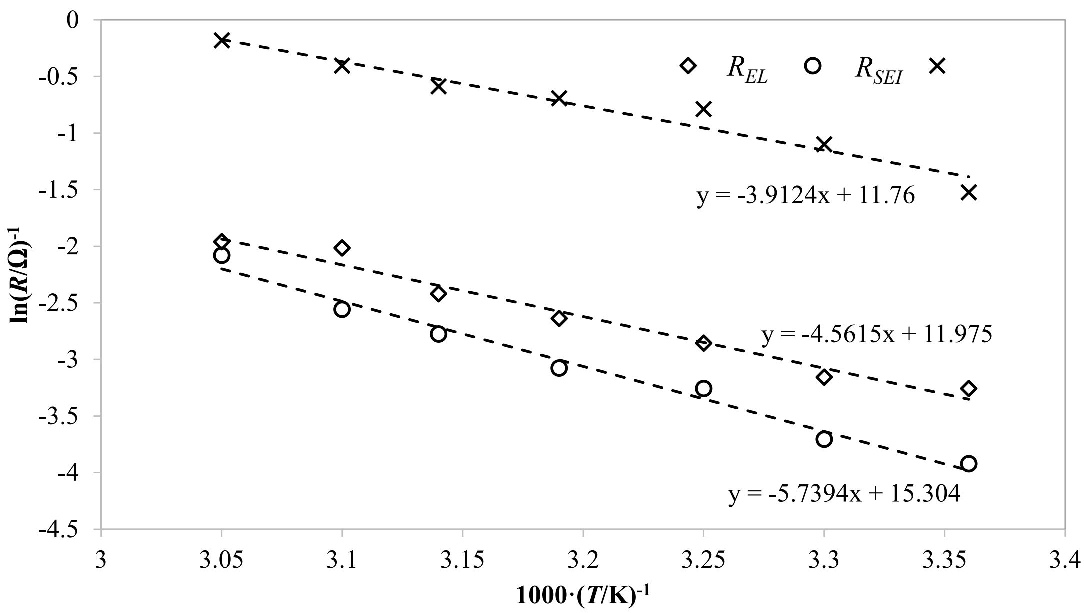

Fig. S2 Arrhenius plot of the half-cell with MoS_2 anode

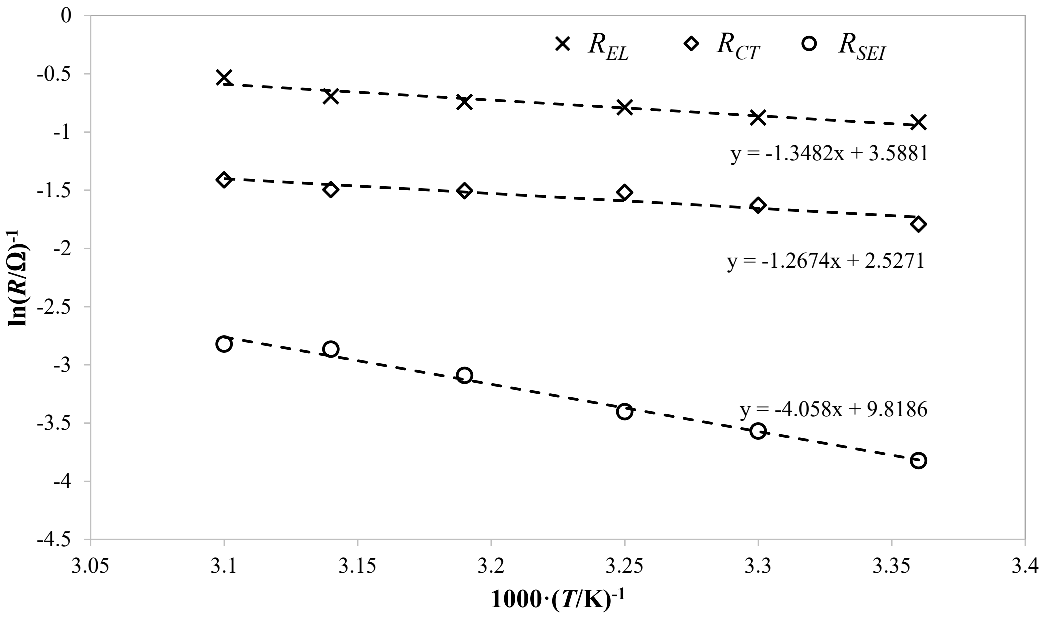

Fig. S3 Arrhenius plot of the half-cell with Sb_2S_3 anode

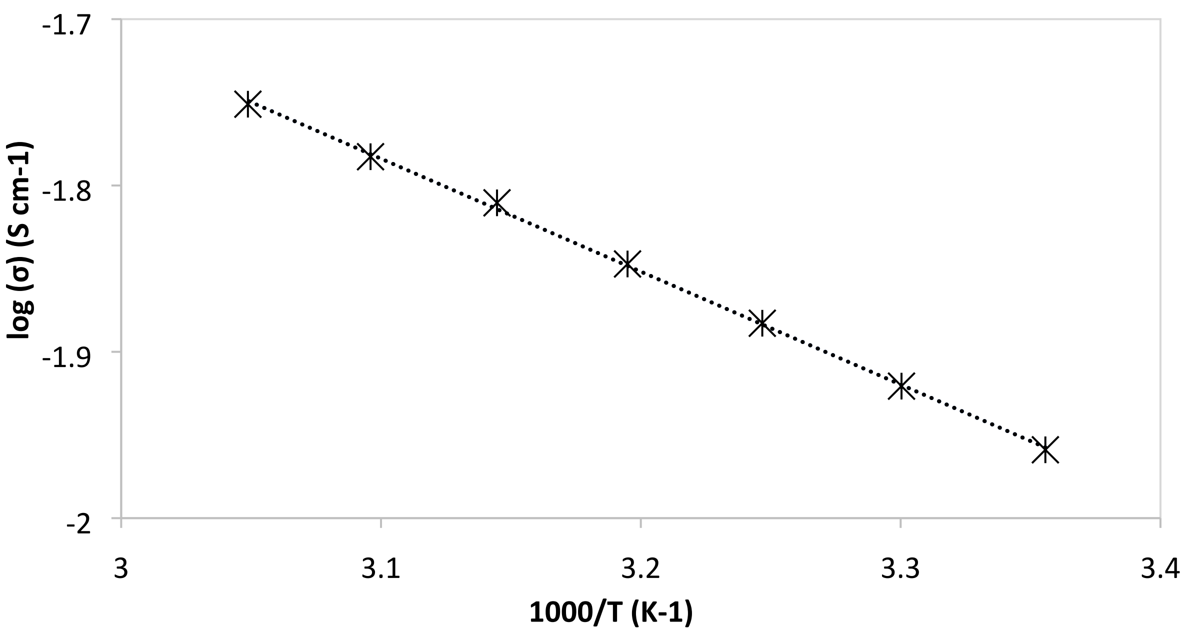

Fig. S4 The log(σ)=f(100/T) dependency for 0.8 M $NaPF_6$ in EC:DMC (1:1 w/w) electrolyte

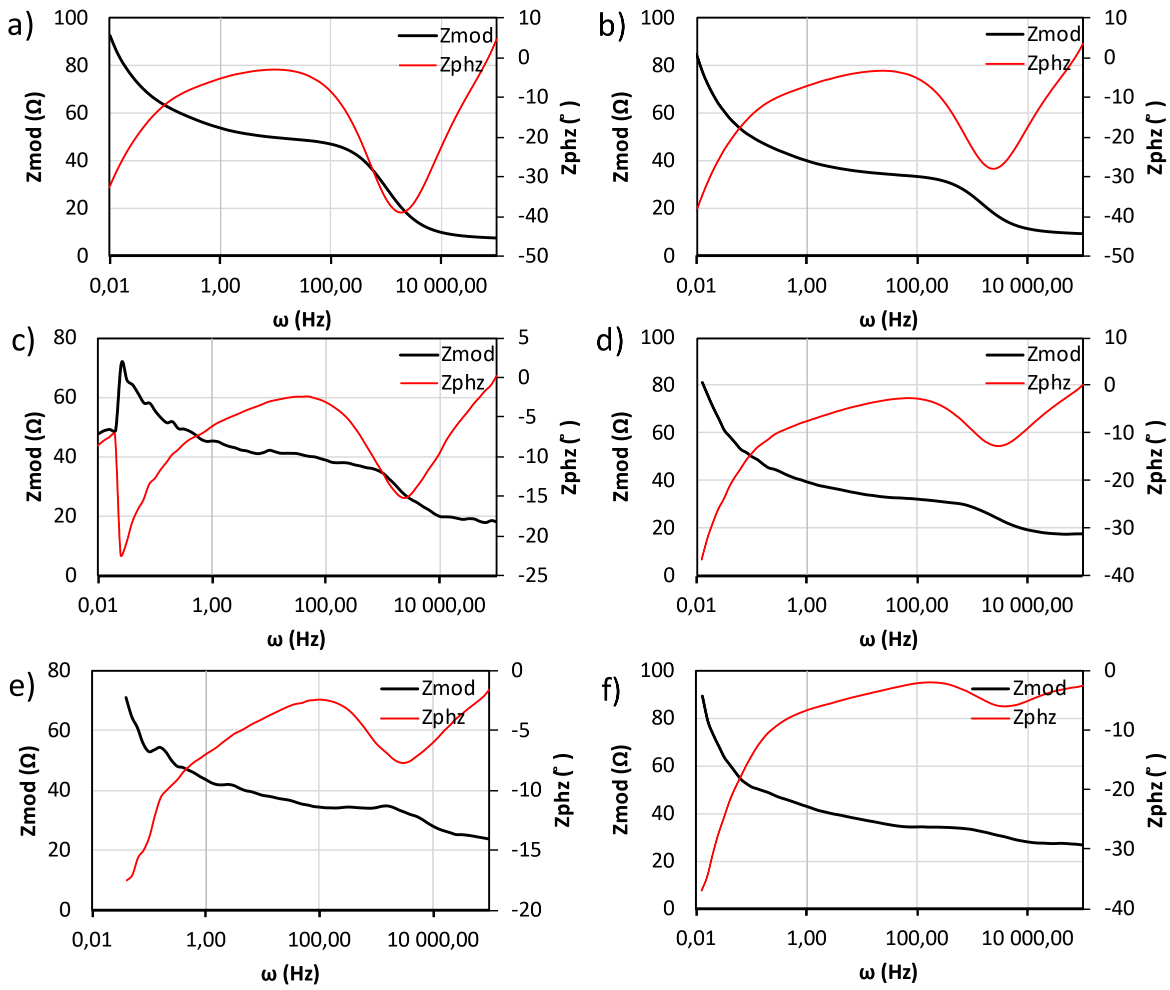

Fig. S5 Bode magnitude and phase plot for MoS_2 anode at (a) 30 °C; (b) 35 °C; (c) 40 °C; (d) 45 °C; (e) 50 °C; (f) 55°C

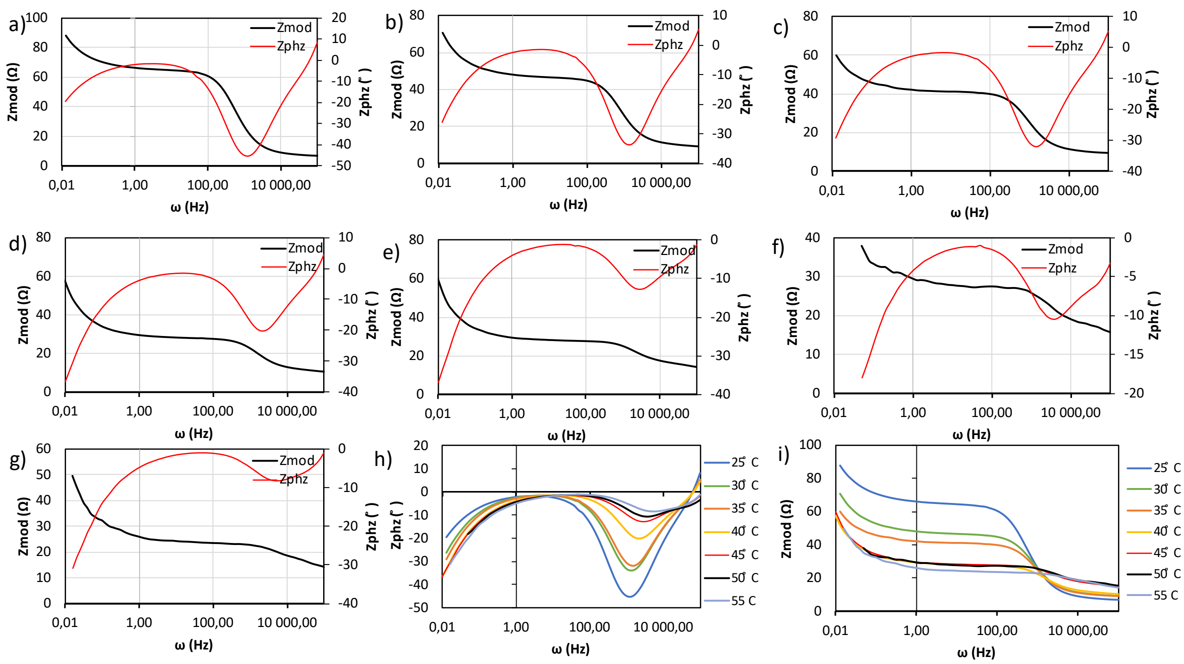

Fig. S6. Bode magnitude and phase plot for SnS at (**a**) 25 °C; (**b**) 30 °C; (**c**) 35 °C; (**d**) 40 °C; (**e**) 45 °C; (**f**) 50 °C; (**g**) 55 °C; (**h**) comparison of Z_{phz} at different temperatures; (**i**) comparison of Z_{mod} at different temperatures.

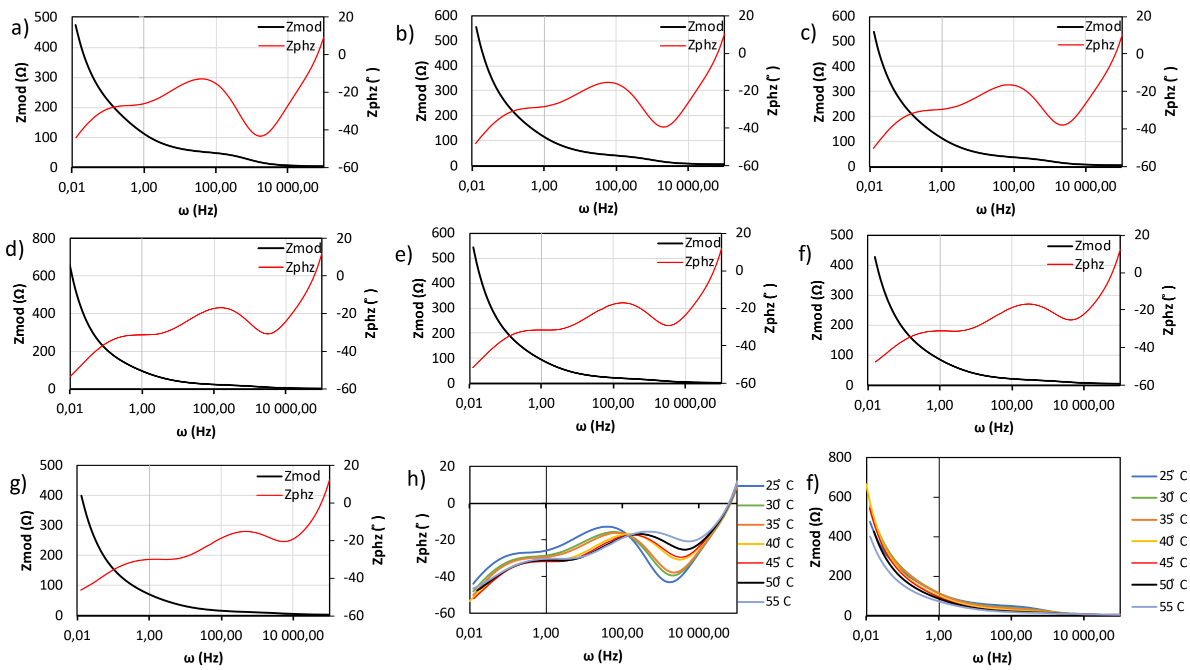

Fig. S7. Bode magnitude and phase plot for Sb_2S_3 at (**a**) 25 °C; (**b**) 30 °C; (**c**) 35 °C; (**d**) 40 °C; (**e**) 45 °C; (**f**) 50 °C; (**g**) 55 °C; (**h**) comparison of Z_{phz} at different temperatures; (**i**) comparison of Z_{mod} at different temperatures.

The Bode plots presented in Fig. S6 (SnS) and Fig. S7 (Sb_2S_3) allow to analyze the changes of impedance properties of these materials in the temperature range from 25 °C to 55 °C. With increasing temperature, a decrease in impedance modulus (Z_{mod}) is observed, suggesting increased electrical conductivity for the SnS anode (Fig. S6i). The characteristic change of Z_{mod} indicates an improvement in charge carrier mobility at higher temperatures. Similar to SnS, the impedance modulus decreases for Sb_2S_3 (Fig. S7i) with temperature, but this decrease can be more noticeable or less intense depending on the electronic structure and transport properties. It is possible that the conductivity of Sb_2S_3 increases to a greater extent than SnS, if the impedance decreases faster.

It is worth noting that if the Z_{mod} for Sb_2S_3 decreases faster than for SnS, it means that Sb_2S_3 shows better conductivity at higher temperatures. If the Z_{mod} decrease in SnS is slower, then this material may be more electrically stable under changing temperature conditions.

The phase angle (Z_{phz}) for SnS (Fig. S6h) changes with temperature, indicating the influence of temperature on the capacitive and resistive properties of the material. It is possible that SnS maintains a more stable impedance profile, suggesting that there are no significant changes in the charge transport mechanism. If the phase angles change more for Sb_2S_3 (Fig. S7h) than for SnS, it indicates that Sb_2S_3 may have a more complex electrochemical response at different temperatures. The strong changes in Z_{phz} may indicate a reduction in capacitive effects and a greater dominance of electron transport mechanisms. If the changes in Z_{phz} for Sb_2S_3 are more abrupt than for SnS, it suggests a greater sensitivity of Sb_2S_3 to temperature. If SnS exhibits a more stable phase angle profile, it could mean that its dielectric properties remain more predictable over a wide temperature range.

SnS may have better impedance stability, meaning its electrochemical properties change less with temperature. Sb_2S_3 may have better conductivity at higher temperatures, but at the cost of greater phase angle variability, which may affect its use in devices requiring stable parameters.

Table S2 Comparison of two anode materials

CHARACTERISTIC	SnS	Sb_2S_3
Impedance modulus (Z_{mod})	Decreases gradually with temperature	Decreases more rapidly, suggesting better conductivity
Phase angle (Z_{phz})	More stable, smaller changes	Larger changes, more dynamic response to temperature
Thermal stability	Higher – smaller property changes	Lower – larger impedance changes
Electrical conductivity	May be lower at higher temperatures	Better conductivity at higher temperatures
Applications	Stable photovoltaic cells, thermoelectric materials	Sensors, electrochemical devices requiring higher reactivity