Directly Embedded Ni$_3$S$_2$/Co$_9$S$_8$@S-Doped Carbon Nanofiber Networks as Free-standing Anode for Lithium-ion Batteries

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To further confirm the composition of the as-prepared samples, we performed a TGA analysis under air atmosphere. The process involved combustion of carbon, oxidation-reduction reaction of metal sulfides:

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\text{Metal sulfide + Carbon nanofibers + O}_2 \rightarrow \text{Metal oxide + CO}_2 + \text{SO}_2
\]

Where the metal sulfide composites were oxidized to NiO and Co$_3$O$_4$. Based on this formulation the weight percentages of Co$_9$S$_8$, Ni$_3$S$_2$/Co$_9$S$_8$, and Ni$_3$S$_2$ in the composites are calculated to be 50.7%, 41.5%, and 39.5%, respectively.

Figure S1. TGA analysis of all the samples under air atmosphere
Figure S2. (a) nitrogen $N_2$ adsorption-desorption isotherms (b) pore-size distribution of the electrodes
Figure S3. SEM image of Ni$_3$S$_2$/Co$_9$S$_8$@S-CNFs anode after 200 cycles at a current density of 1 A g$^{-1}$
Figure S4. The relationship plot of $Z'$ versus $\omega^{-1/2}$ at low-frequency region.

The Li diffusion kinetics was analyzed via EIS by using the following equation:

$$D = \frac{R^2T^2}{2A^2n^2F^4C^2\sigma^2}$$  \hspace{1cm} \text{Equation S1}

Where R is the gas constant, T represents the temperature, A is the surface area of electrode, F is the Farady constant, $n$ is the number of electrons per molecule attending the charge-discharge reaction, C is the concentration of lithium ion in the electrode, and $\sigma$ is the slop of the line $Z' - \omega^{-1/2}$. Based on the equation, the lithium ions diffusion coefficient is inversely proportional to $\sigma$ (shown in Figure S4).