Single-step microwave mediated synthesis of CoS$_2$ anode material for high rate hybrid supercapacitors

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Supporting information

Figure S1: Lithiation of as-prepared conversion-type negative electrode material i.e., CoS$_2$ nanoflakes, at a current rate of 1.0 A g$^{-1}$. A fresh cell containing CoS$_2$ against metallic Lithium in 1M LiPF$_6$ (EC:DMC, 1:1 by v/v) electrolyte was galvanostatically cycled between 0.3 – 3.0V. The cell was stabilized for 10 cycles before being used for supercapacitor application. A stable capacity of ~270 mAh g$^{-1}$ was obtained after 10 cycles. The cell was stopped after finishing the discharge of 10$^{th}$ cycle and the composite electrode containing sulfide was immediately transferred to the hybrid supercapacitor (HSC) cell inside a glove box, thus assembling the lithiated form of HSC. The HSC was further tested electrochemically for elucidating the effect of lithiation. There was no deviation in the specific capacitance of the lithiated form of HSC when the current rate during lithiation was changed.
Figure S2: Cyclic voltammograms of (a) non-lithiated CoS₂ and (b) lithium-doped CoS₂ between 0 – 3 V at various scan rates against an AC cathode. Both cells showed typical rectangular shaped curves at all scan rates. More importantly, the potential of the lithiated CoS₂ electrode was higher than that of the corresponding non-lithiated sample, which showed the positive effect of lithiation. The lithiated sample had a higher potential, reaching a maximum of 2.2 V, while the non-lithiated sample did not show a rise in potential.
Figure S3: (Top) Evaluation of half cells of CoS$_2$ and activated carbon and optimization of the mass ratio based on the individual capacity obtained. An optimized mass ratio of 1:3 for AC vs. CoS$_2$ was achieved and used throughout the study. The voltage of the hybrid supercapacitor CoS$_2$/AC was limited to 0-3V for safe operation in order to avoid electrolyte decomposition. (Bottom) Cycle life characteristics of CoS$_2$/Li half cell at 1 mA g$^{-1}$ between 0.3 and 3.0V.
**Figure S4:** Cycling curves of hybrid supercapacitors operating at a current rate of 2.7 A g\(^{-1}\) containing non-lithiated and lithiated CoS\(_2\) active materials against the AC cathode.
Figure S5: XPS spectra of as-prepared CoS$_2$ nanoflakes showing the Co 2p and S 2p bands.

Calculation for energy and power density:
The specific energy density (ED) and power density (PD) for the cells were determined from charge-discharge studies as follows:

\[ PD = \frac{IV}{2m} \text{ (W kg}^{-1}) \]

\[ ED = PD \times \frac{t}{3600} \text{ (Wh kg}^{-1}) \]

where \( m \) is the mass of active materials from both electrodes, \( I \) the current applied, \( t \) the discharge time and \( V \) the cell voltage.