Supporting Information

A High-Performance Li-Metal Free Sulfur Battery Employing Lithiated Anatase TiO_2 Anode and Free Standing Li_2S-Carbon Aerogel Cathode

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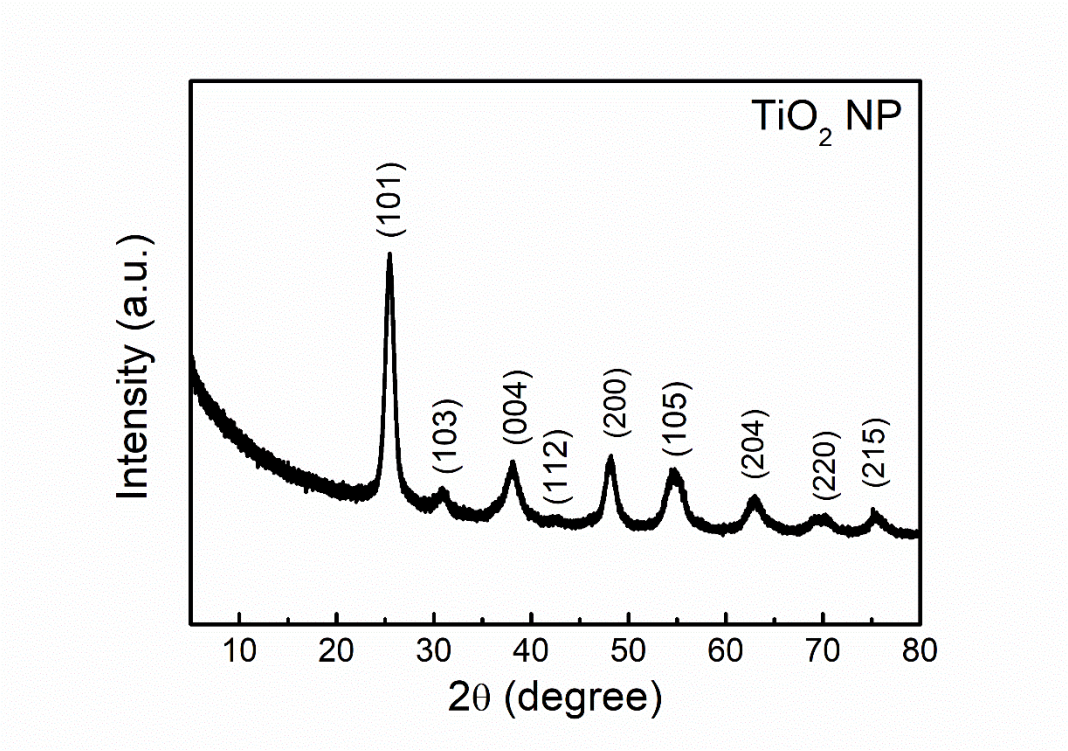

Figure S1. X-ray diffraction pattern of TiO_2 nanoparticles

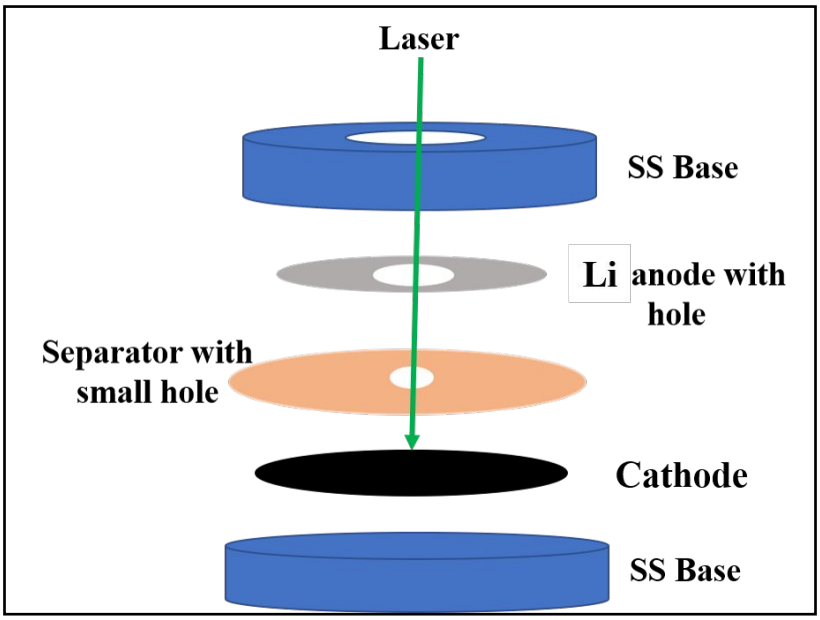

Figure S2. Schematic of cell used for operando Raman measurements

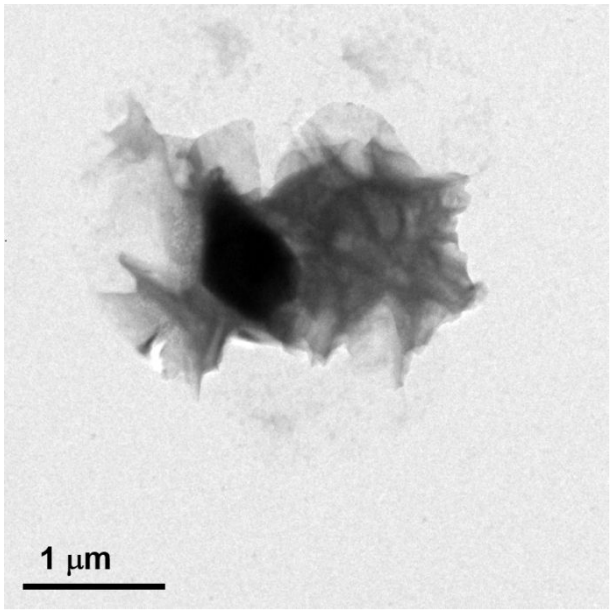

Figure S3. Bright-field TEM image of Li_2S nanostructure

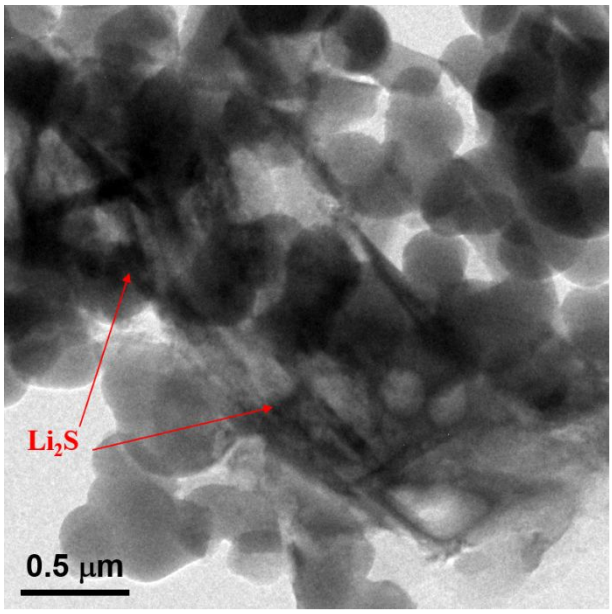

Figure S4. Bright-field TEM image of pelletized Li_2S/CA cathode.

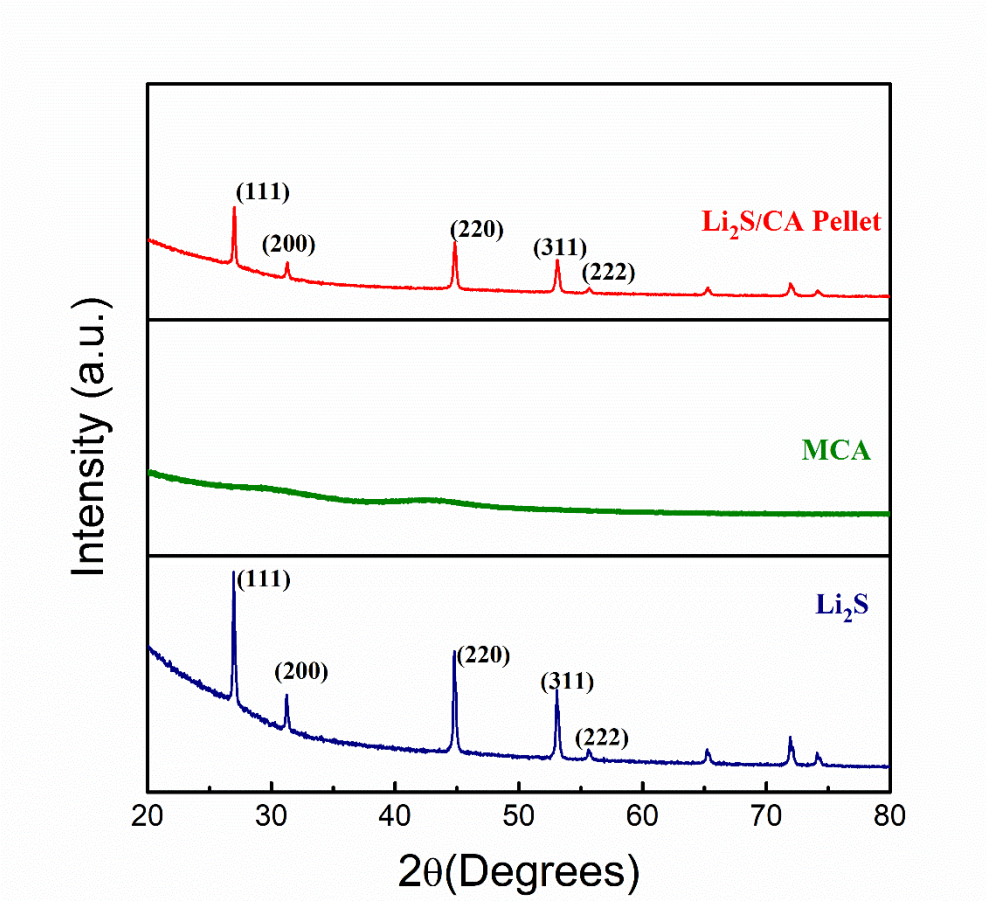

Figure S5. Powder-XRD pattern of Li_2S powder (blue), CA (green) and Li_2S/CA pellet red.

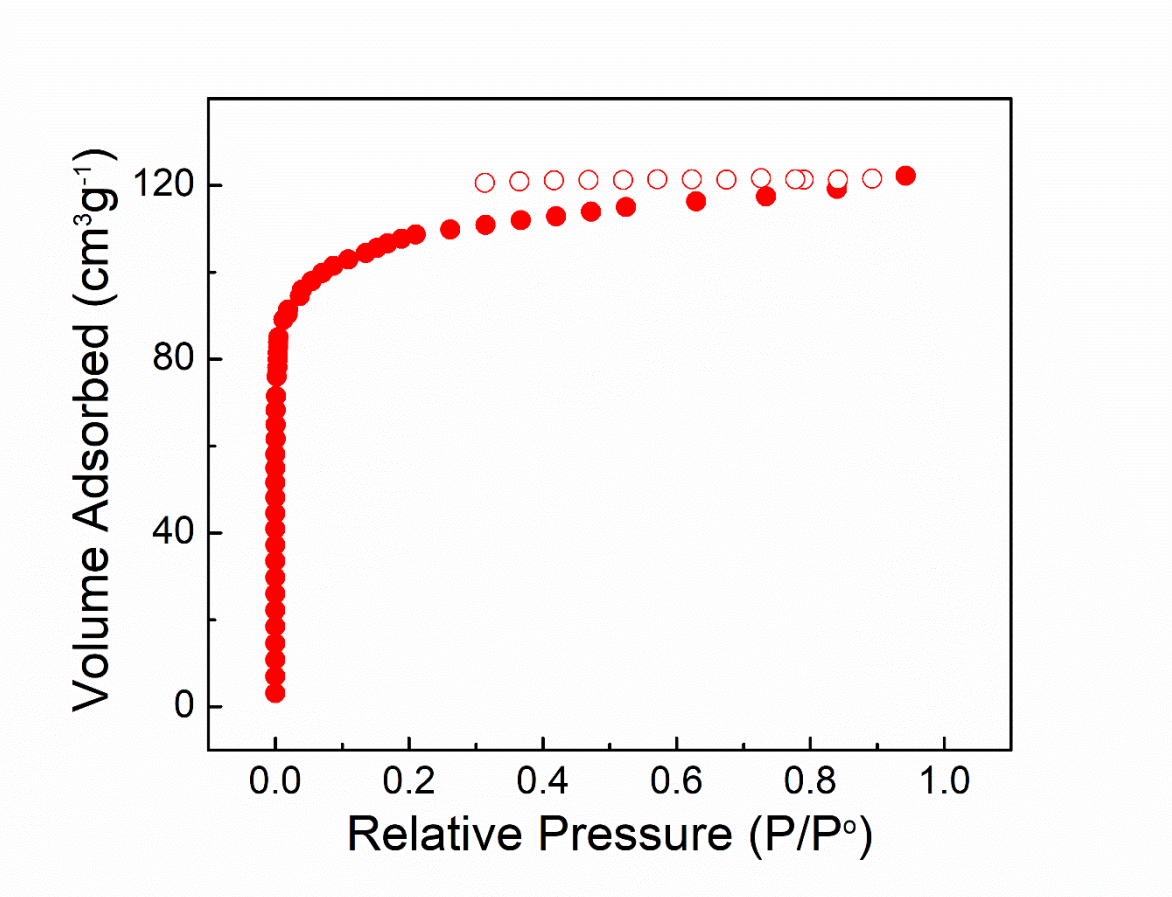

Figure S6. N_2 adsorption/desorption isotherms of CA

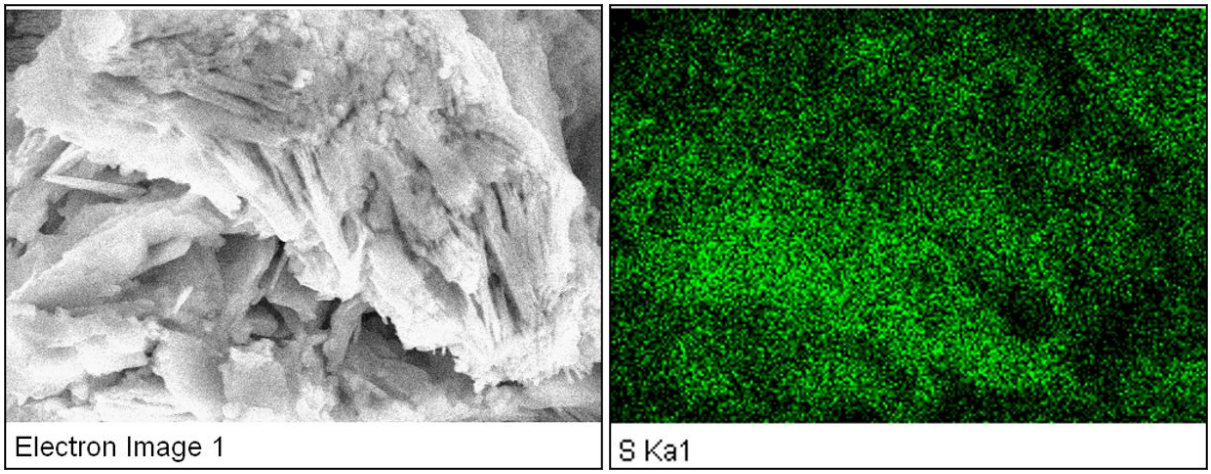

Figure S7. SEM image and elemental mapping of Li_2S

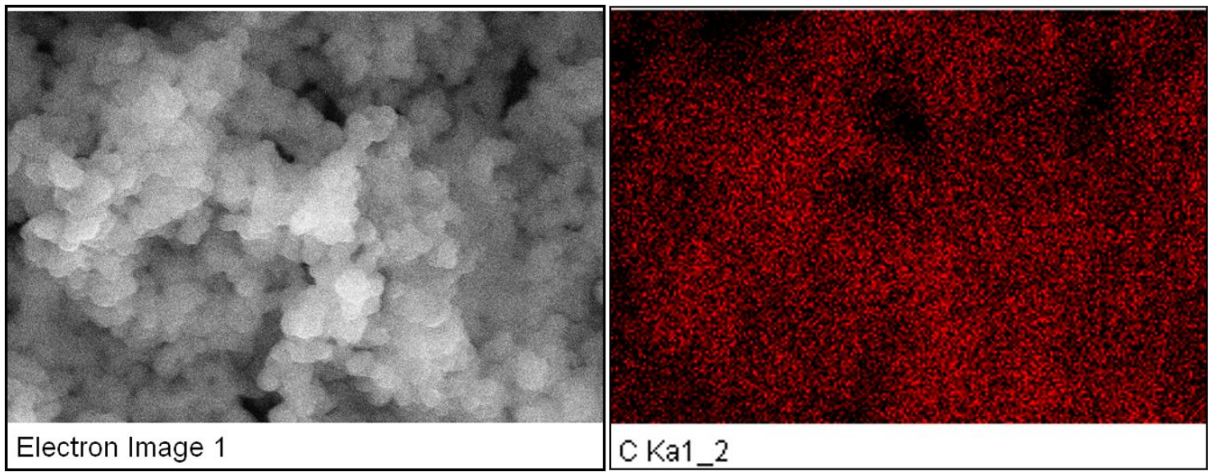

Figure S8. SEM image and elemental mapping of CA

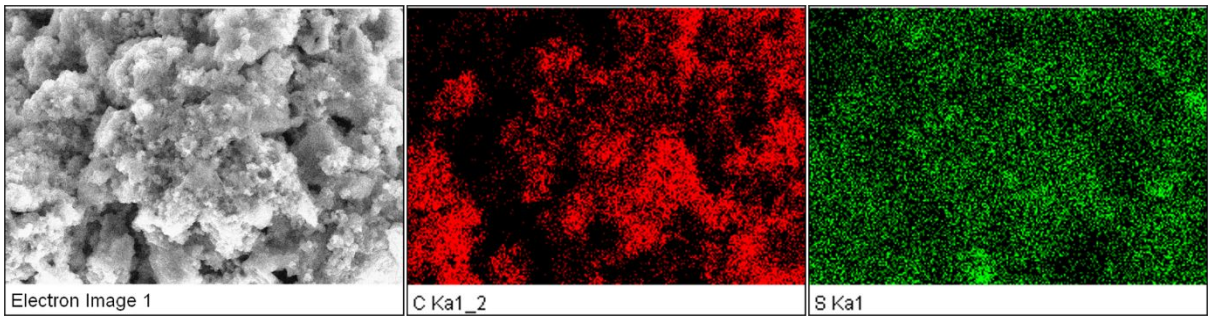

Figure S9. SEM image and elemental mapping of Li_2S/CA composite cathode

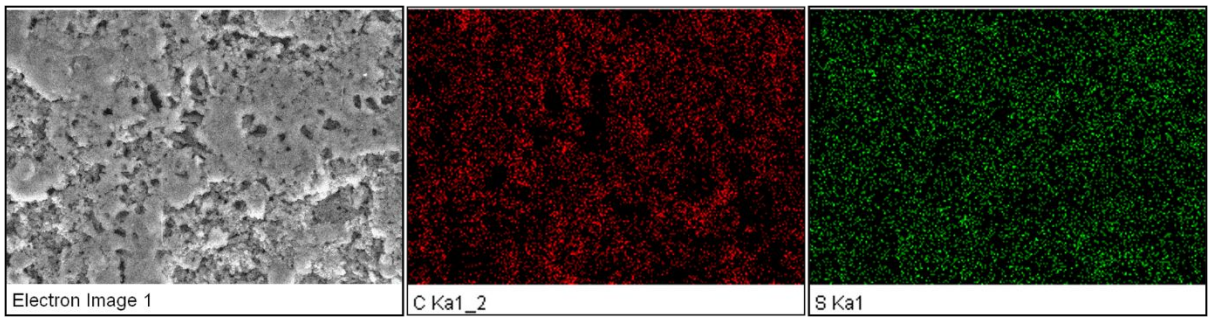

Figure S10. SEM image and elemental mapping of Li_2S/CA cathode after activation cycle.

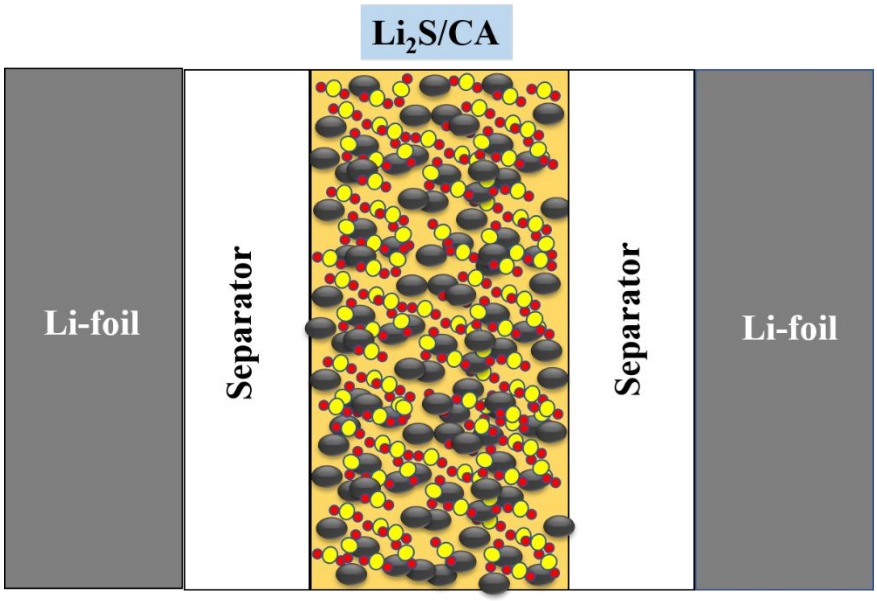

Figure S11. Schematic of the symmetric cell employed for measuring the tortuosity of the Li_2S/CA pellet.

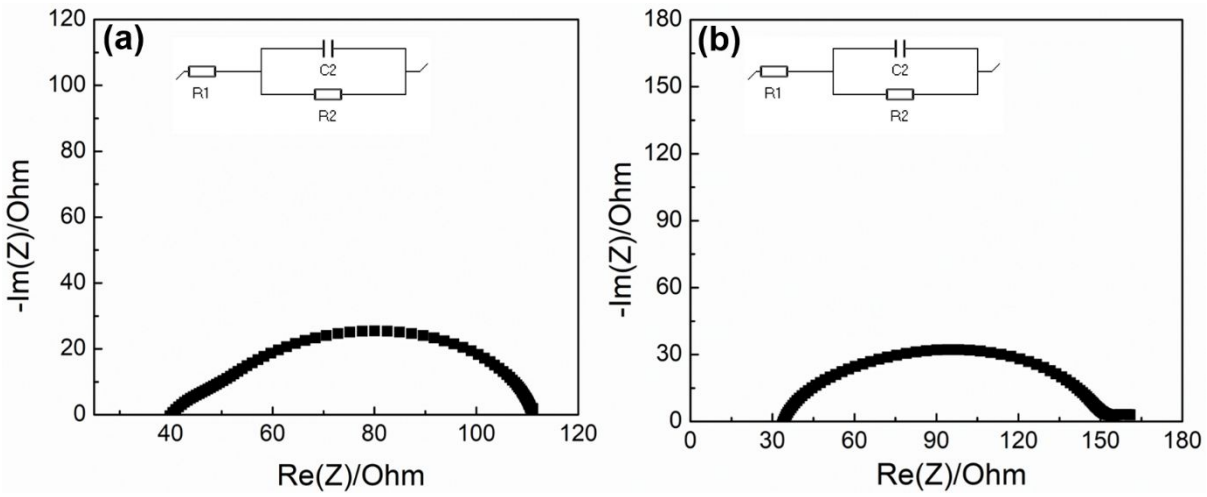

Figure S12. Nyquist plot and equivalent circuit for the Li_2S/CA pellet obtained (a) Without separator, (b) With separator.

The Li_2S/CA pellet is placed between separators placed between lithium foil electrodes. The tortuosity was obtained using the following expression:

$$\sigma_P = \sigma\varphi\tau^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots S1$$

where,

σ_P: effective conductivity (with separator as figure S10) = 7.14×10^{-5} S/cm

σ: intrinsic conductivity (without separators) = 1.2×10^{-4} S/cm

φ: Volume fraction of pores = 0.60

τ: Tortuosity of the materials as per equation S1 = 1.06

σ_P and σ are ionic conductivity in the presence and absence of separator. Volume fraction of pores were obtained by estimating the density from calculated sample volume and weight.

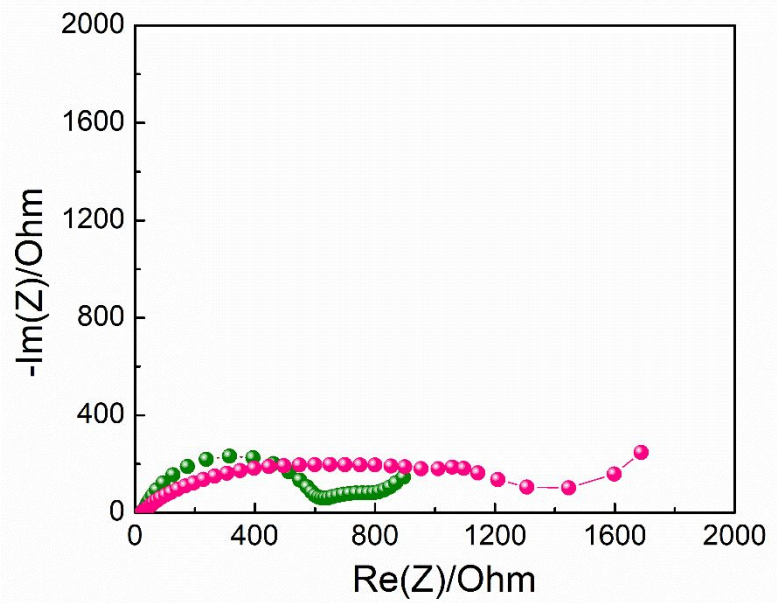

Figure S13. Electrochemical Impedance spectroscopy (EIS, Nyquist plot) of the Li/S cell with Li_2S/CA cathode, at OCV (green), after activation (pink).

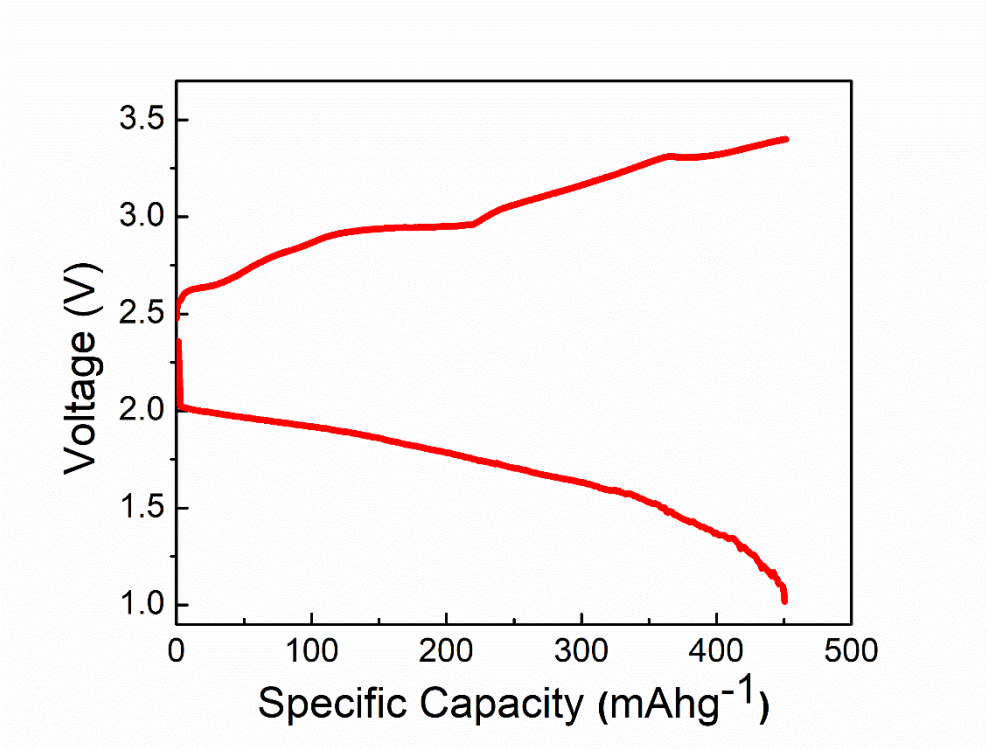

Figure S14. Galvanostatic charge/discharge profile of Li_2S/Gr full cell

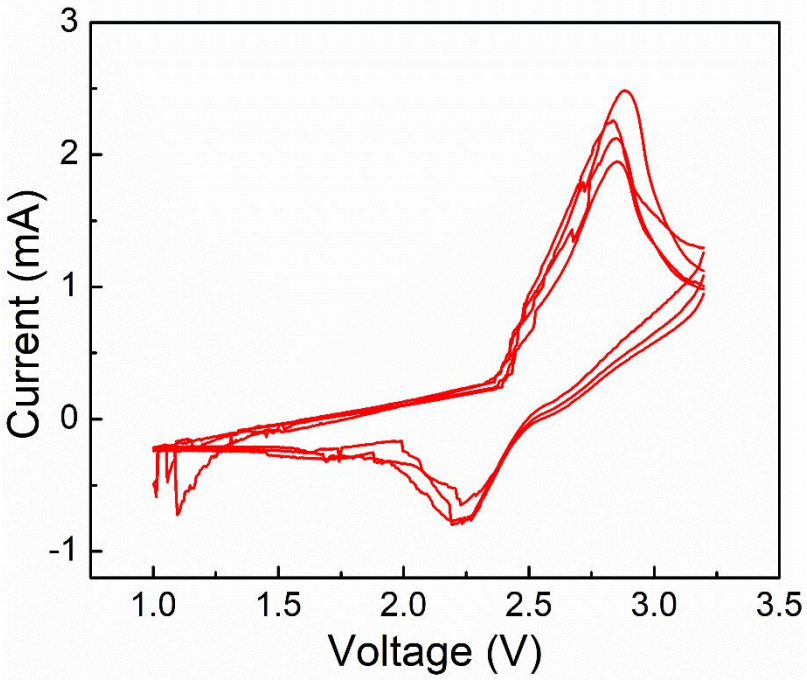

Figure S15. Cyclic voltammograms of Li_2S/Gr full cell.

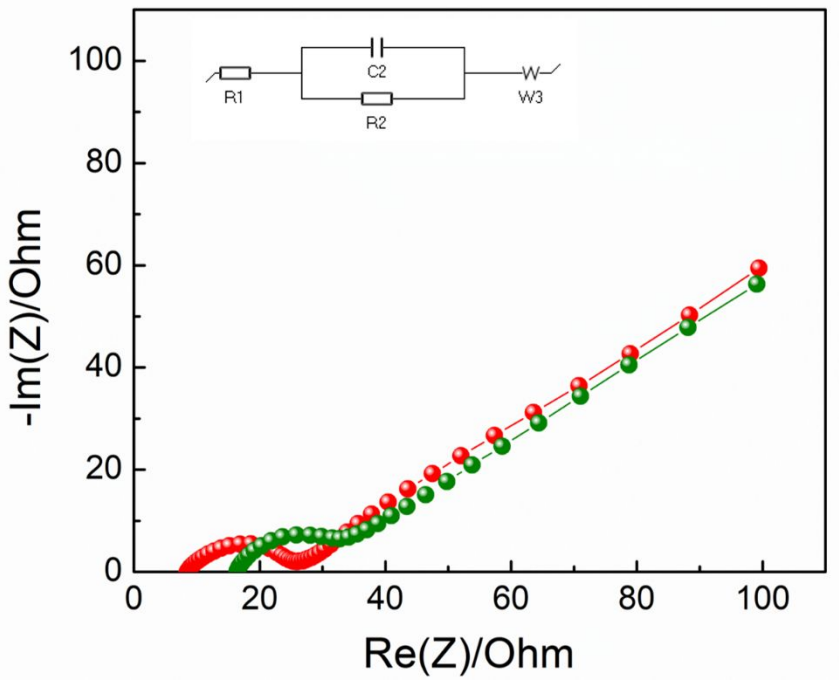

Figure S16. Electrochemical Impedance spectroscopy (EIS, Nyquist plot) of the Li||TiO_2 cell (red) and Li||Gr cell (green). Inset shows the equivalent circuit for fitting the data.

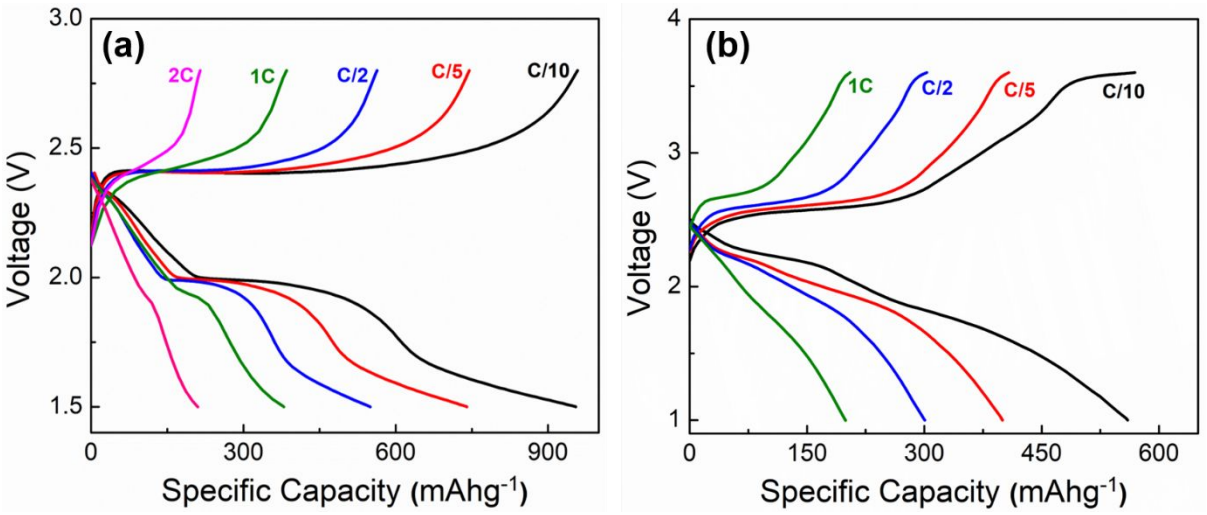

Figure S17. Rate capability of the Li-S cell with (a) Li_2S/CA cathode and lithium anode, (b) Li2S/CA cathode and TiO_2 anode

Table S1. A comparison of the energy density of the present work with other previously reported Li_2S based full cells.

Cathode	Anode	Capacity @ first discharge	Number of cycles	Energy Density (Wh/kg)	Reference
Li_2S mesoporous carbon composite cathode	Silicon nanowire anode	423 mAh g^{-1}	20	720	1
Li_2S-MCMB composite	Si-O-C anode	228 mAh g^{-1}	50	390	2
Li_2S/C composite Cathode	Graphite anode	750 mAh g^{-1}	300	1300	3
Nano compacted Li_2S/Graphene composite	Graphene	800 mAh g^{-1}	100	1400	4
Li_2S/Carbon aerogel pellet cathode	Anatase TiO_2 anode	566 mAh g^{-1}	200	1300	Current work

Cell parameters of the Li_2S/TiO_2 cell using TiO_2 anode and Li_2S/CA cathode

Materials	**Weight (mg)**
Li_2S	7.8
Carbon aerogel (CA)	3.4

TiO_2	27.3
Carbon (acetylene black)	3.4
PVDF binder	3.4
Al-Current collector	5.0
electrolyte	87.5
Separator	13.2
Total weight	**151**

Cell capacity (mAh) = 4.41

Nominal cell voltage (V) = 2.3 V

Energy density of the cell based on the active mass of Li_2S = $\frac{\text{Cell capacity}}{\text{weight of Li2S(g)}}\times$ Cell voltage ..S2

$$= \frac{4.41}{7.8\times10^{-3}}\times 2.3$$

$$\approx 1300 \text{ Wh/Kg}$$

Energy density of the cell based on the total weight of the cell = $\frac{\text{Cell capacity}}{\text{total weight (g)}}\times$ Cell voltage

$$= \frac{4.41}{151\times10^{-3}}\times 2.3$$

$$\approx 30 \text{ Wh/Kg}$$

Table S2. A comparison of the energy density of the Li_2S/CA||TiO_2 cell with the commercial LIBs comprising intercalation compounds cathode and graphite anode.

Cell Chemistry	Anode	Cathode	Nominal Voltage	Energy Density (Wh/kg)
Lithium cobalt oxide	Graphite	$LiCoO_2$	3.7	195
Lithium iron phosphate	Graphite	$LiFePO_4$	3.2	160
Lithium nickel cobalt aluminium oxides	Graphite	NCA	3.6	220
Lithium nickel manganese cobalt oxide	Graphite	NMC	3.6	205
Li_2S/Carbon aerogel pellet cathode	Anatase TiO_2 anode	Li_2S/CA pellet	2.3	1300 (Current work)

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