

Electronic Supplementary Information

Highly conductive porous graphene/sulfur composite ribbon electrodes for flexible lithium sulfur batteries

Woon Gie Chong^a, Youhua Xiao^b, Jian-Qiu Huang^a, Shanshan Yao^a, Jiang Cui^a, Lei Qin^a, Chao Gao^b, Jang-Kyo Kim*^a

^a Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

^b MOE Key Laboratory of Macromolecular Synthesis and Functionalization, Department of Polymer Science and Engineering, Key Laboratory of Adsorption and Separation Materials & Technologies of Zhejiang Province, Zhejiang University, 38 Zheda Road, Hangzhou 310027, PR China

* Email: mejkkim@ust.hk

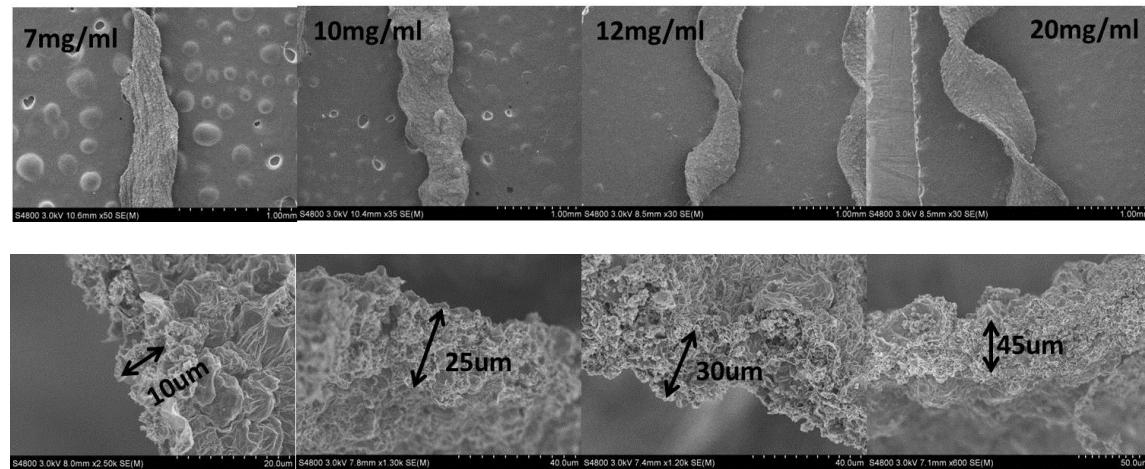


Fig. S1 SEM images of rGO/GC/S composite ribbons prepared by wet spinning of dope with different concentrations.

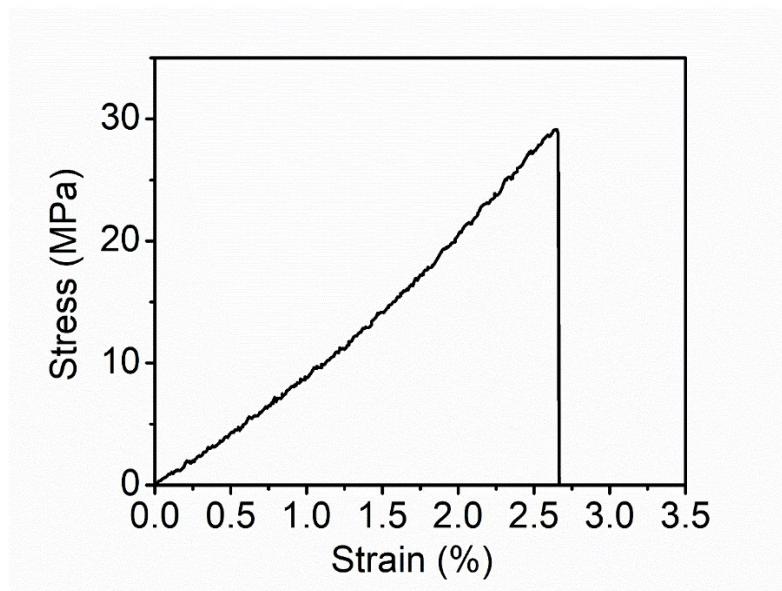


Fig. S2 Stress-strain curve of GO paper prepared by vacuum infiltration.

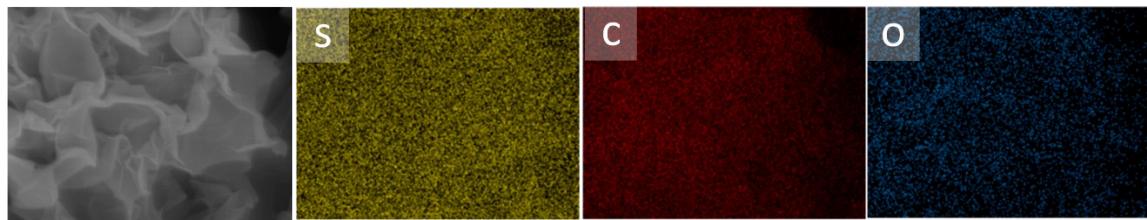


Fig. S3 SEM images of GC/S composite.

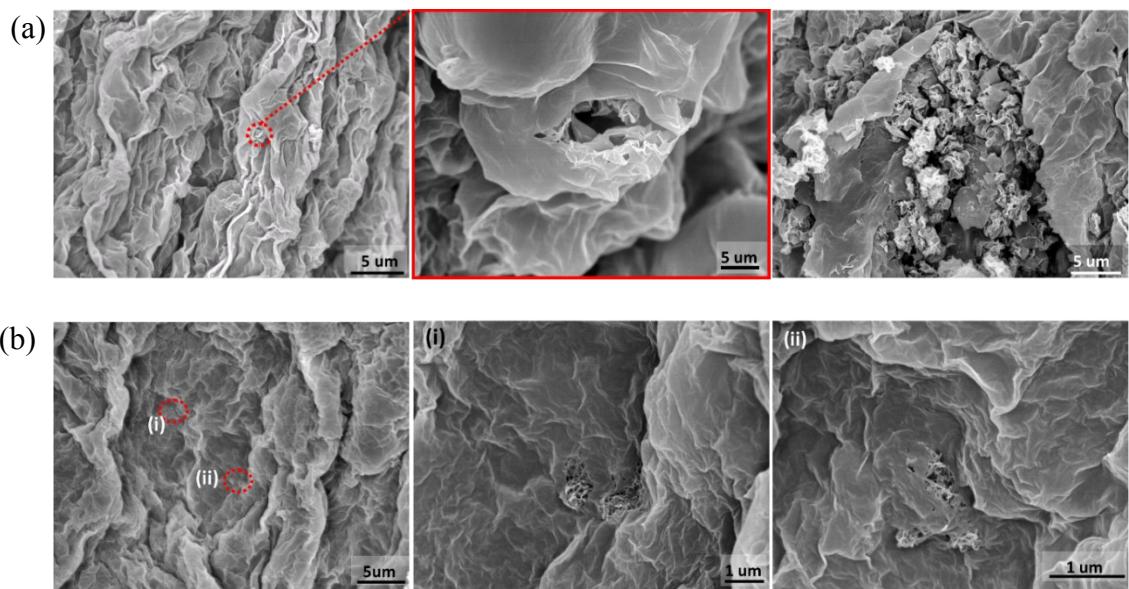


Fig. S4 SEM images of (a) 1rGO/2GC/S and (b) 1rGO/1CNT/S composite ribbons; damages to the ribbon surfaces indicated by red circles.

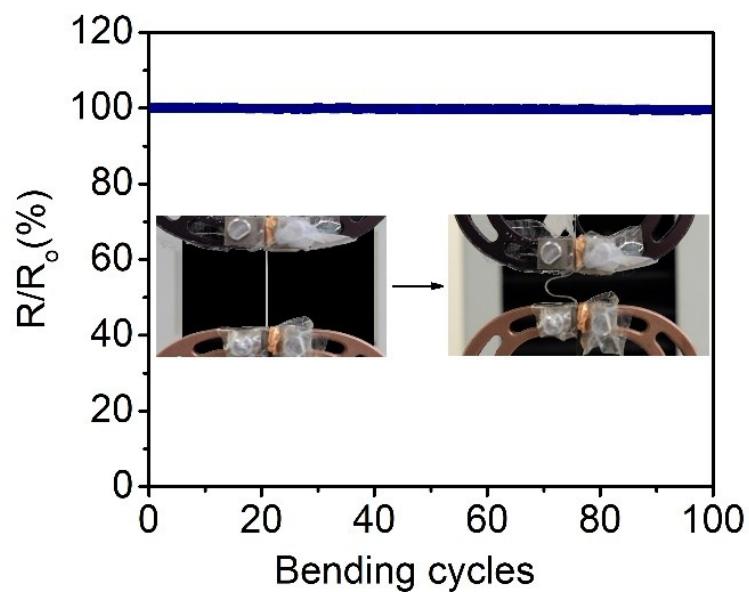


Fig. S5 Normalized electrical resistance, R/R_o , of 1rGO/1GC/S ribbon electrode measured by bending/flattening cycles (the inset pictures describing the bending process). R is the instantaneous resistance and R_o is the initial resistance of the electrode.

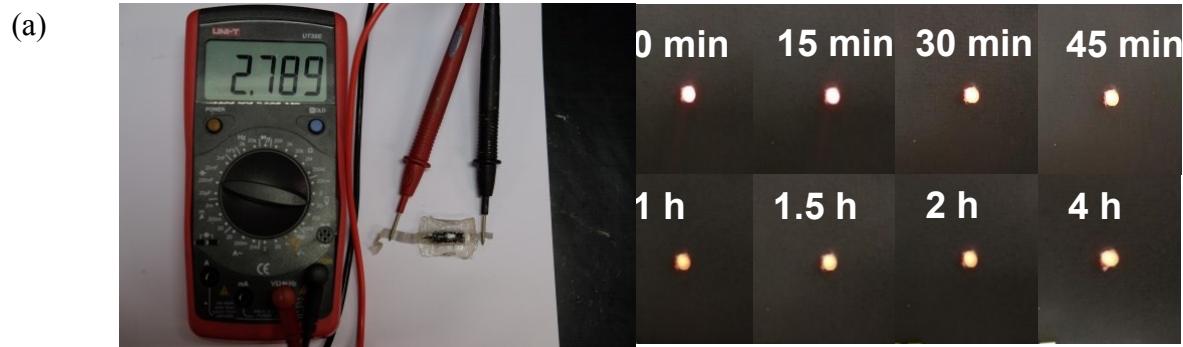


Fig. S6 (a) Open circuit voltage and (b) the lighting performance of a red LED powered by the stretchable LSB.

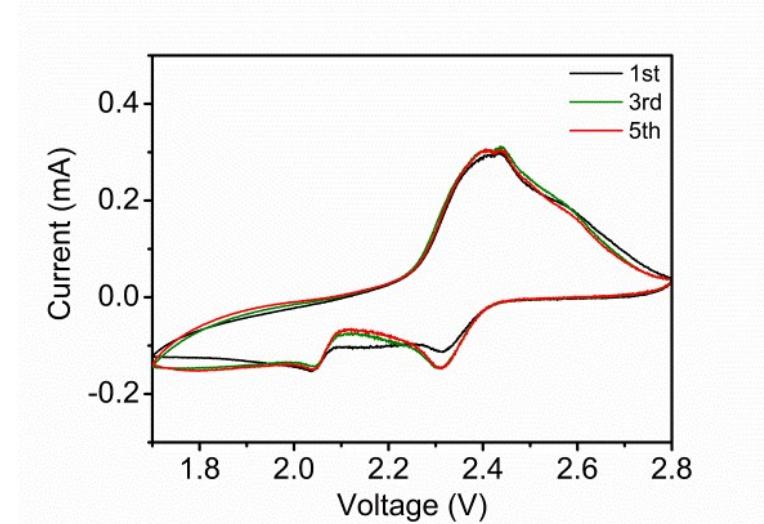


Fig. S7 CV curve of the 1rGO/1CNT/S electrode in the first 5 cycles.

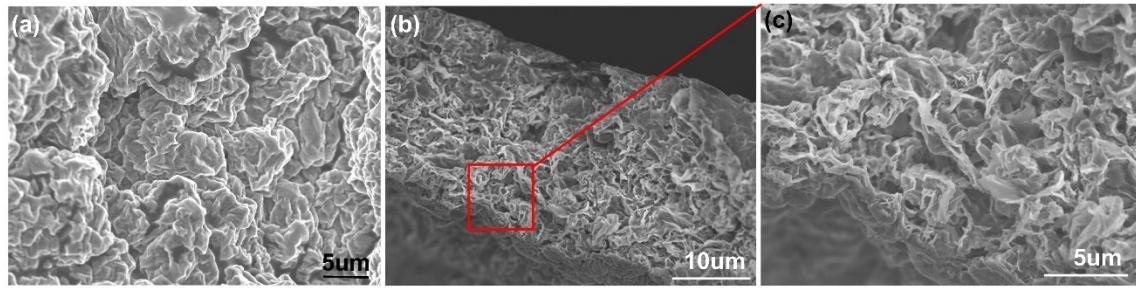


Fig. S8 (a) Surface and (b-c) cross-sectional SEM images of the 1rGO/1GC/S electrode after 50 cycles.

Table S1. Impedance parameters, R_e , R_{st} and R_{ct} , determined from the EIS data in Figures 6e-f.

Electrodes	Cycle	R_e (Ω)	R_{st} (Ω)	R_{ct} (Ω)
1rGO/1GC/S	0	2.93	56.4	165
	50	2.15	26.2	54.0
1rGO/2GC/S	0	2.76	174	224
	50	2.99	23.3	130
1rGO/1CNT/S	0	7.43	146	284
	50	7.30	46.5	78.0

Table S2. Comparison of electrochemical performance between the current 1rGO/1GC/S LSB and representative flexible sulfur cathodes reported in the literature.

Cathode	Sulfur content (%)	Sulfur loading (mg/cm ²)	Current density	Cycle s	Capacity Retention (%)	Gravimetric energy density (Wh kg ⁻¹)	Ref
rGO coated porous carbon-sulfur nanofiber	58.4	1.5	0.1C	200	78	1309.77	[14]
Wet spun rGO/CNT/S	45	2	0.1C	100	33.1	873.6	[17]
Graphene/sulfur deposited stainless steel fibers	35.58	N/A	0.1C	100	70	1606.5	[18]
Sulfur impregnated activated carbon fiber cloth	33.3	6.5	150mA/g	80	75.7	1680	[60]
Electrodeposited sulfur/G on Carbon fiber	33	0.8-1.3	200mA/g	50	49.16	1050	[61]
N-doped carbon foam/S/GO	61	3.2	0.1C	100	69.7	1344	[62]
Electrospun CNF+CNT-Sulfur cathode	40	0.8	50mA/g	100	40	1337.7	[63]
Mesoporous graphene paper	55	0.36	0.1C	50	49.5	1446.9	[64]
Binder free 3D sulphur/few-layer graphene foam	52	2	0.47C	50	63.2	1087.8	[65]

Free-standing carbon paper supported Li ₂ S	36	1.4	0.1C	100	52.4	903	[67]
Flexible sulfur yarns-pellets	30-40	5.4	0.1mA/g	55	74	1050	[68]
Sulfur/Carbon Nanotube Composite Film	65	3.25	0.1C	100	67	1554	[69]
1rGO/1GC/S ribbon	42	1.22	0.2C	100	73.4	1192	This work

Table S3. Comparison of electrochemical performance between the current 1rGO/1GC/S ribbon LSB and representative 1D fiber- or wire-shaped rechargeable batteries.

Cathode	Anode	Voltage (V)	Current density	Active Material (%)	Specific Capacity (mAh g ⁻¹)	Cycles	Energy Density (Wh kg ⁻¹)	Ref
CNT-Si/CNT composite yarn	Li	0.4	1A/g	38.1	1670	100	668	[7]
CNT/LMO	CNT/Si	3.4	148 mA/g	75 vs 62	106.5	100	362.1	[8]
GO/CMK-3@S-CNTF	Li	2.1	167.5	68	570	100	1197	[16]
rGO/CNT/S	Li	2.1	167.5	45	416	100	873.6	[17]
3D printed LFP	Li	3.45	50mA	31.58	160	30	552	[23]
3D printed LTO	Li	1.5	50mA	31.58	150	30	225	[23]
CNT/MnO	Li	1.5	5×10^{-4}	4.1	218.32	100	327.48	[70]

mA								
CNT/LiMnO4	Li	4	0.05mA	90	60	200	240	[71]
CNT/LTO	Li	1.5	0.05mA	78	150	200	225	[71]
Polyimide/CNTF	LMO/CNTF	1.4	1.83A/g	51	120	1500	48.93	[72]
Fe2O3/CNTY	Li	1	800mA/g	30.4	423.4	100	423.4	[73]
rGO/SnO2@CF	Li	0.45	50mA/g	80	293	100	131.85	[74]
Slurry coat LFP/CF	Slurry coat LTO/CF	1.9	1C	88	NA	100	65	[75]
Wetspun rGO/TiO6	Li	1.75	0.0170 mA	90	168	100	294	[76]
1rGO/1GC/S	Li	2.1	335	42	524	100	1100.4	This work