Supporting Information

A hollow carbon foam for integrated cathode with ultra-high sulfur loading in lithium-sulfur battery

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After taking into account the articles involved high sulfur loading Li-S battery from January 2011 to June 2016, the study results over 70% sulfur loading in cathode were listed in Table.S1.

Note: meanings of the "method" are as follows:

1: Directly increasing the sulfur loading in S/C composites with the traditional slurry method

2: Using the interlayer, modified separator and modified current collector in the traditional slurry method

3: Designing integrated electrode without additive

Table.S1 study results of high Sulfur loading (over 70%) Li-S battery from 2011 to 2016

Materials	Method	Sulfur loading		Current density	Cycle number	Cycling performance		Ref.
		%	mg/cm^2			initial	final	
Three-dimensional graphene framework	3	90%	4.32	0.1C	50	1100	750	1
3D Graphene-Reduced Graphene Oxide Hybrid Networks	3	83%	9.8	0.2C	350	1000	645	2
Monoclinic Sulfur encapsulated in aligned nanotubes	3	80.85%	1	2C	1000	1138	863	3
Three-Dimensional Sulfur/Graphene Multifunctional Hybrid Sponges	3	80%	12	0.1C	300	513	471.4	4
Porous carbon current collector	2	80%	2.3	0.1C	100	1200	961	5
Various porous current collectors	2	80%	2	0.01C	12	1400	1200	6
SWCNT-modulated separators	2	78%	6.3	0.2C	150	1132	720	7
Graphene-wrapped sulfur Nano spheres	1	77.40%	2	0.1C	100	972	430	8
Aligned Carbon nanotube/sulfur composite	1	76.50%	1.98	0.1C	90	736.8	600	9
Hierarchically porous carbon	1	75%	——	0.1C	25	1305	469	10
this work	**3**	**75%**	**2.27**	**0.1C**	**100**	**1134**	**653**	**——**
Hollow Carbon nanofiber	3	75%	1	0.1C	150	1400	730	11
Carbonized bacterial cellulose	2	75%	1.1-1.6	200mA/g	150	1134	800	12
Three-dimensional CNT/graphene–sulfur hybrid sponges	1	72.90%	1	0.1C	200	1179.6	975	13

Highly crumpled nitrogen-doped graphene sheets	1	72%	5	0.1C	200	1082	833	14
Reduced graphene oxide-hollow carbon sphere	1	72%	3	0.1C	100	840	620	15
Multidimensional Nano carbon−Sulfur hybrid materials	1	72%	2	0.02C	50	1239	600	16
Three-dimensional porous carbon composites	1	72%	2.36	2C	200	1115	920	17
Free-standing MWCNT interlayer	2	70%	——	1C	100	1400	804	18
Polyethylene glycol-supported microporous carbon	2	70%	——	0.2C	500	1307	782	19
Non-woven fabric films as adsorbing interlayers	2	70%	2	0.1C	100	1486	858	20
Sulfur-graphene-polypropylene separator integrated electrode	2	70%	1.5-2.1	1.5A/g	500	~980	663	21
Sandwich-structured sulfur cathode	2	70%	1.5	0.2C	100	1495	1100	22
Mesoporous Carbon nanotube network	2	70%	——	0.1C	100	760	528	23
graphene/poly (dimethyl siloxane) foam	2	70%	10.1	1.5A/g	1000	~1000	448	24

Table S2 The elements content of MFC heated at 800 °C for 2 hours and 4 hours

	Carbon elements	Nitrogen elements	Oxygen elements
MFC 800 °C for 2h	66.54 at%	5.05 at %	28.41 at %
MFC 800 °C for 4h	67.87 at %	4.12 at %	28.01 at %

To find out the influence of the second heat treatment, MFC was reheated at 800 °C for another 2 hours. According to its SEM images and XPS pattern, there is no obvious change in structure and morphology, and the content of nitrogen and oxygen decreased slightly. The results show there is limited difference in the structure and element content of the MFC before and after the second heat treatment during the preparation of MFC-rGO.

Table S3 The electronic conductivity of MFC-based carbon foam

	R (Ω)	A (cm^2)	L (um)	σ (S/cm)
MFC-rGO	0.40332	0.785	38.8	0.12355
MFC-GO	3.569	0.785	36.5	0.0130
MFC	4.396	0.785	45.3	0.0131

The electronic conductivities of the MFC-based carbon foams are measured using 2 probes method. The values are given by the equation $\sigma = L/A*R$, where L and A are the length and the contact area of the electrode and R is the measured resistance.

Table S4 The details of MFC-based sulfur electrodes

	Mass of host material	Mass of sulfur		Sulfur loading
MFC-S	0.56mg	1.69mg	75.11%	2.15 mg/cm^{-2}
MFC-GO-S	0.54mg	1.61mg	74.88%	2.05mg/cm^{-2}
MFC-rGO-S	0.59mg	1.78mg	75.11%	2.27 mg/cm^{-2}

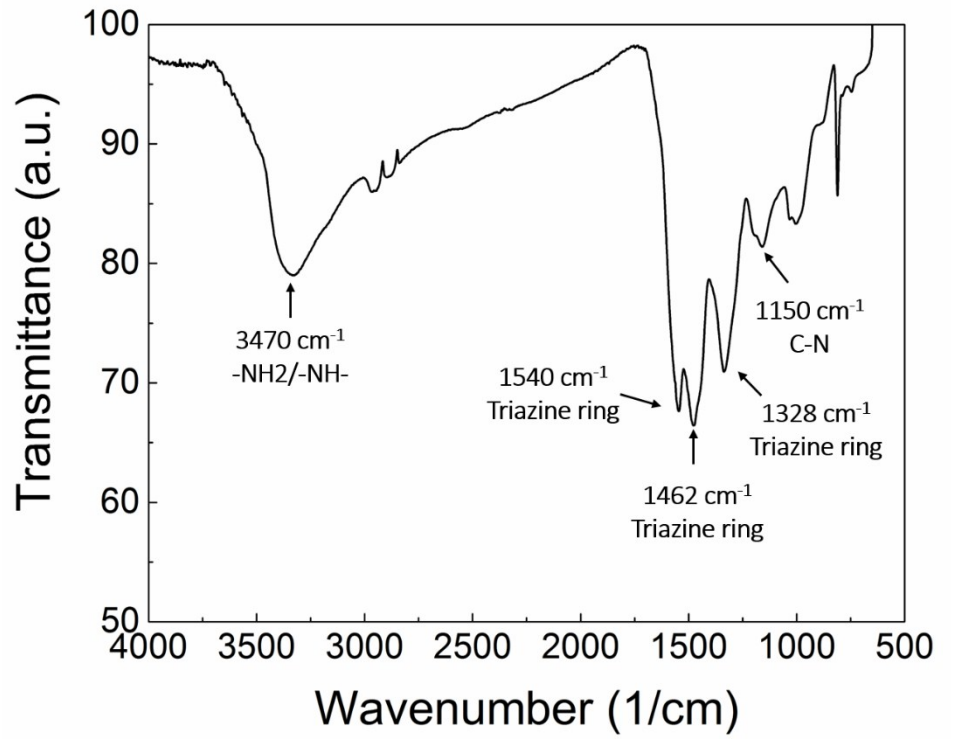

Fig. S1 the FT-IR spectra of commercialized MF foam.

The infrared spectrum was carried out to found out the ingredient of the commercialized melamine foam. As shown in FIG.S1, these absorption peaks and their corresponding functional groups indicate the MF foam was a typical melamine formaldehyde resin.

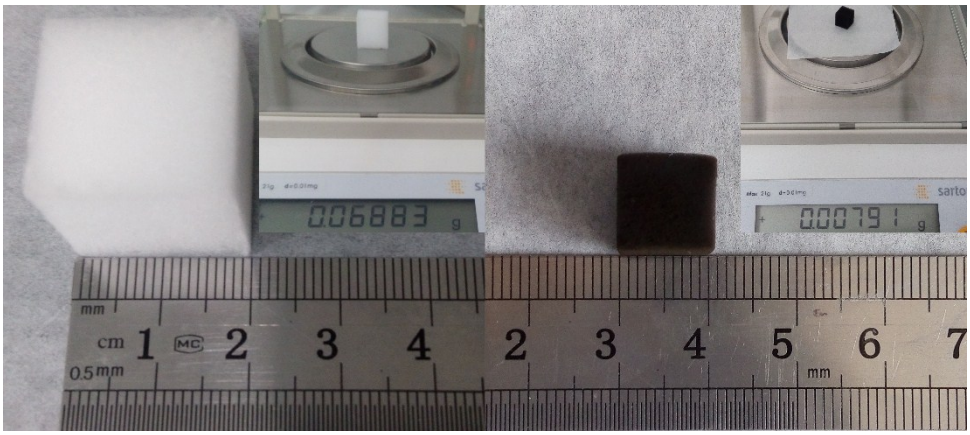

Fig. S2 photographs of MF and MFC foam.

To calculate the yield of the carbonization procedure, a cubic MF foam was carbonized in the same condition. Its mass and volume were shown in Fig. S2, from the results, the yield of the carbonization process was calculated as 11.49%, and the volume decreased to 1/8 of its original value.

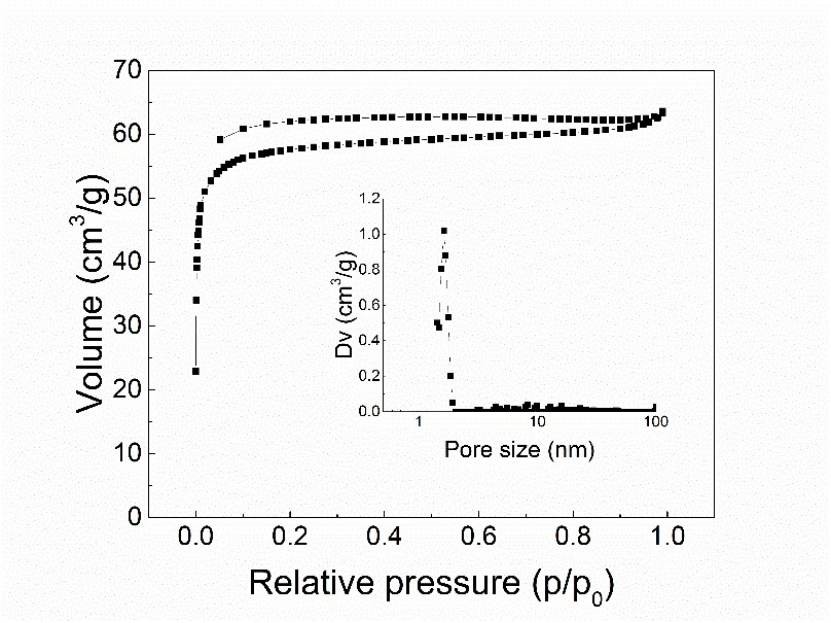

Fig. S3 N_2 adsorption isotherm curves of MFC.

The porous structures of MFC was tested through adsorption-desorption isotherms. According to the result, the specific surface area and pore volume were 219 m²/g and 0.0979 cm³/g respectively.

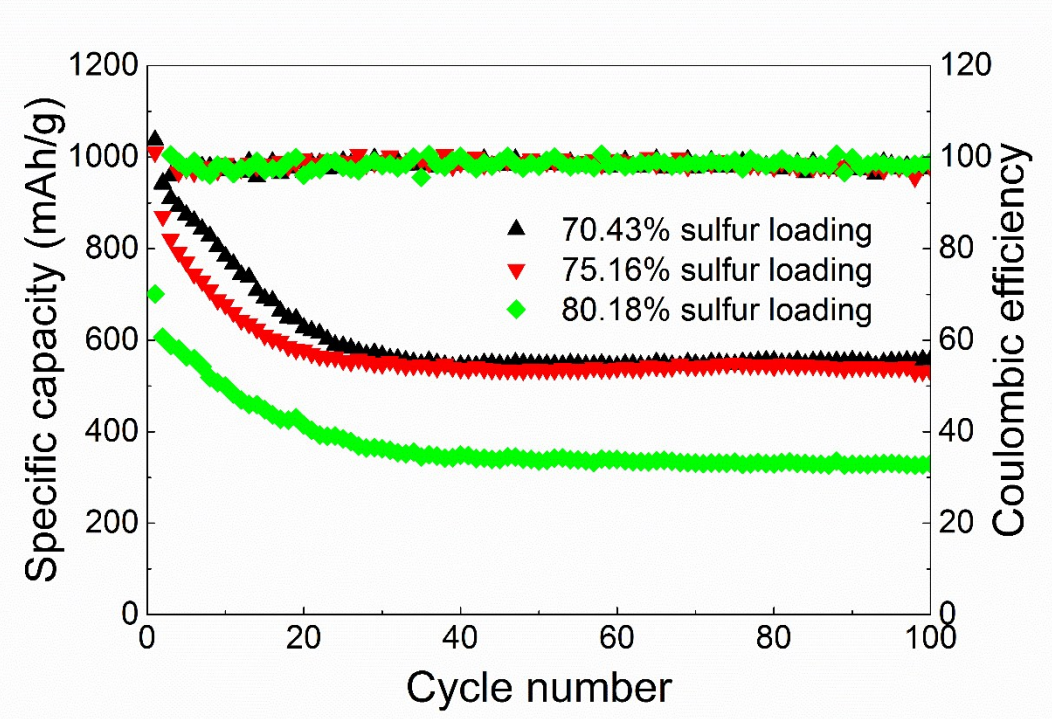

Fig. S4 cycling performances of MFC-S cathodes with different Sulfur loading.

To found out the appropriate Sulfur loading, MFC-S electrodes with different loading were tested in the same conditions. All of these electrodes showed excellent cycling performances left out the inevitable capacity fading in the initial stage. And there was little difference in capacity performance between electrodes below 75.16% sulfur loading, while the capacity decreased sharply when the loading reach up to 80.18%. So it was appropriate to keep the sulfur loading constant at 75% around.

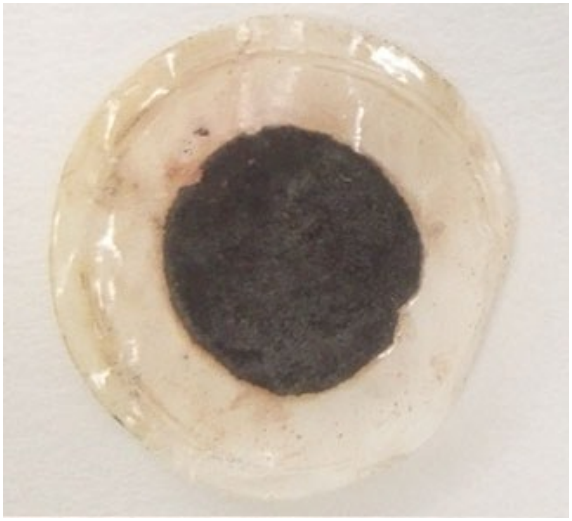

Fig. S5 cycled cathode of MFC-S cathode.

The cycled electrode was shown in FIG S5. As we can see, the entire cathode is attached to separator tightly and remain intact after long cycle.

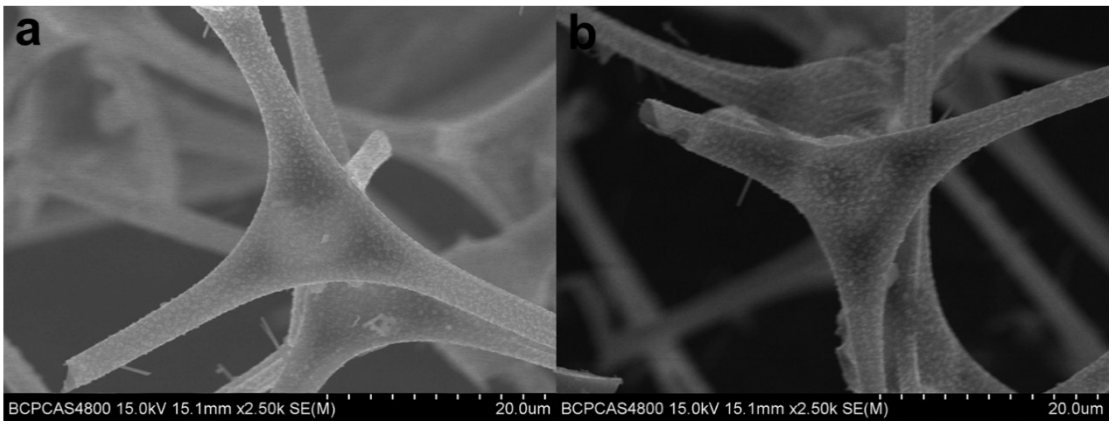

Fig. S6 SEM image of MFC (a) and reheated MFC (b)

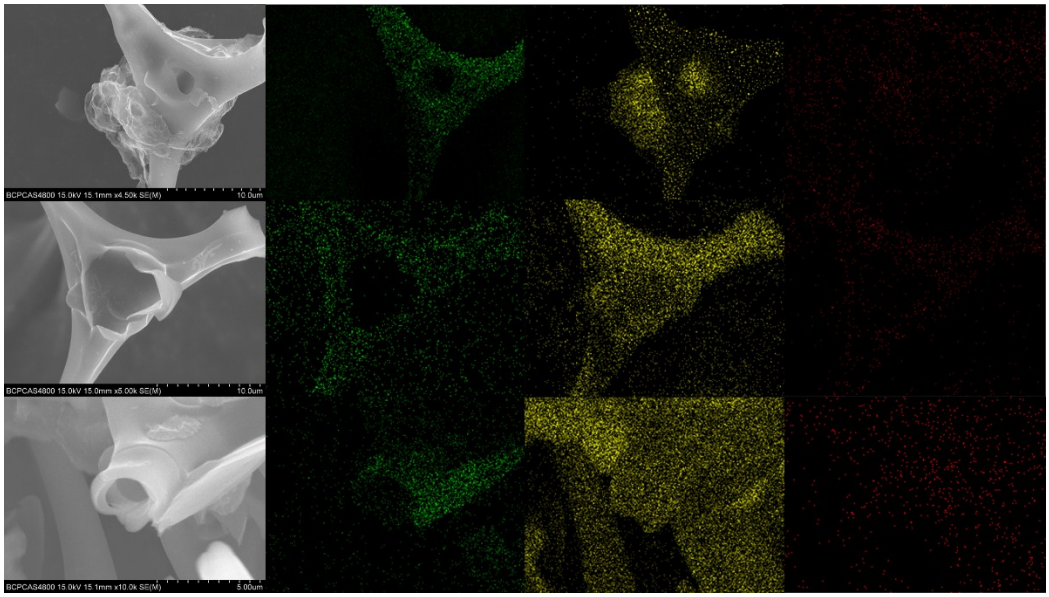

Fig. S7 SEM images and element distribution of MFC-S (a), MFC-GO-S (b) and MFC-rGO-S (c)

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