Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A

Electronic Supplementary Information (ESI)

Plasma-functionalized carbon-layered separators for improved performance of lithium sulfur batteries

Jee Hun Ahn,[ac] Hyun-Jin Shin,[ac] Saleem Abbas,[ab] Kwan Young Lee,[c] Heung Yong Ha*[ab]

[a] Center for Energy Storage Research, Korea Institute of Science and Technology (KIST), 14-gil 5, Hwarang-ro, Seongbuk-gu, Seoul 02792, Republic of Korea.

[b] Department of Energy & Environmental Engineering, Korea University of Science & Technology (UST), 217 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea.

[c] Department of Chemical & Biological Engineering, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul 02841, Republic of Korea.

*Corresponding Author E-mail: hyha@kist.re.kr

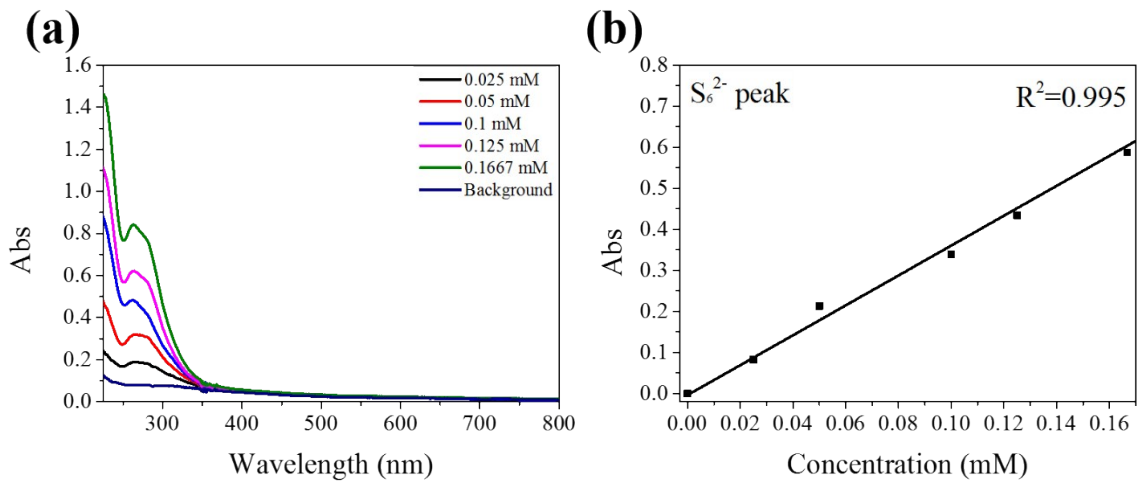

Fig. S1. The characteristic peaks of UV at around 280 nm can be attributed to S_6^{2-} species. A calibration curve was obtained by measuring the absorbance of S_6^{2-} for a set of known concentrations of polysulfide solutions. (a) UV-Vis absorbance spectra of various concentrations of polysulfide solutions and (b) a calibration curve plotting the absorbance vs. the concentration obtained at 280 nm wavelength for S_6^{2-} species.

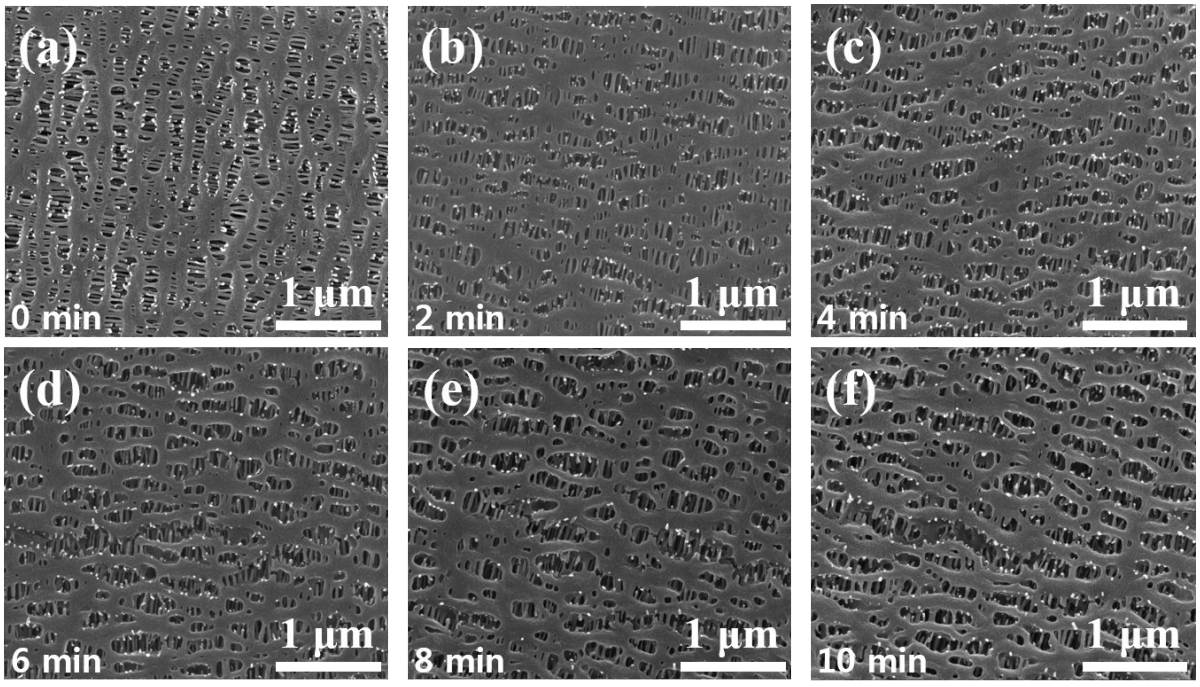

Fig. S2. SEM images of the surfaces of (a) a pristine separator, and the CO_2-plasma-treated separators for (b) 2 min, (c) 4 min, (d) 6 min, (e) 8 min, and (f) 10 min.

Table S1. Porosities of the CO_2-plasma-treated separators.

Plasma treatment time (min)	Porosity (%)
0	38.2
2	39.7
4	41.2
6	42.1
8	42.6
10	45.2

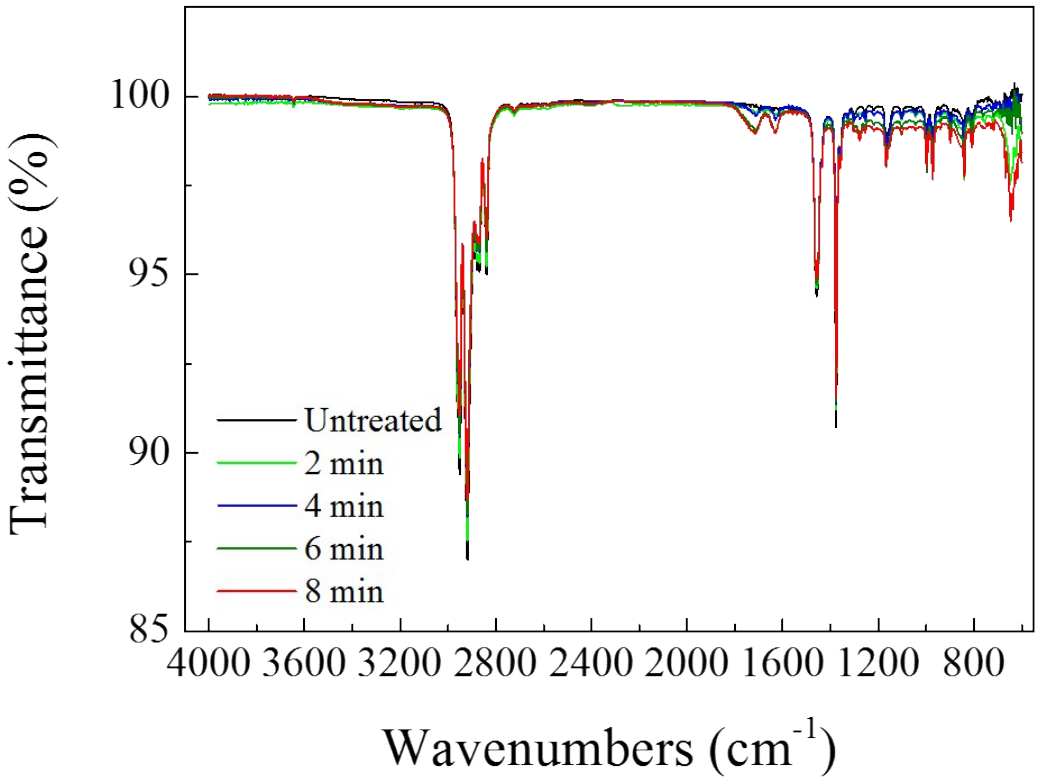

Fig. S3. FTIR spectra of the bare polymer separators treated with a CO_2-plasma for 0, 2, 4, 6, and 8 min, respectively. The amounts of functional groups increase until 6 min and thereafter are maintained almost constant.

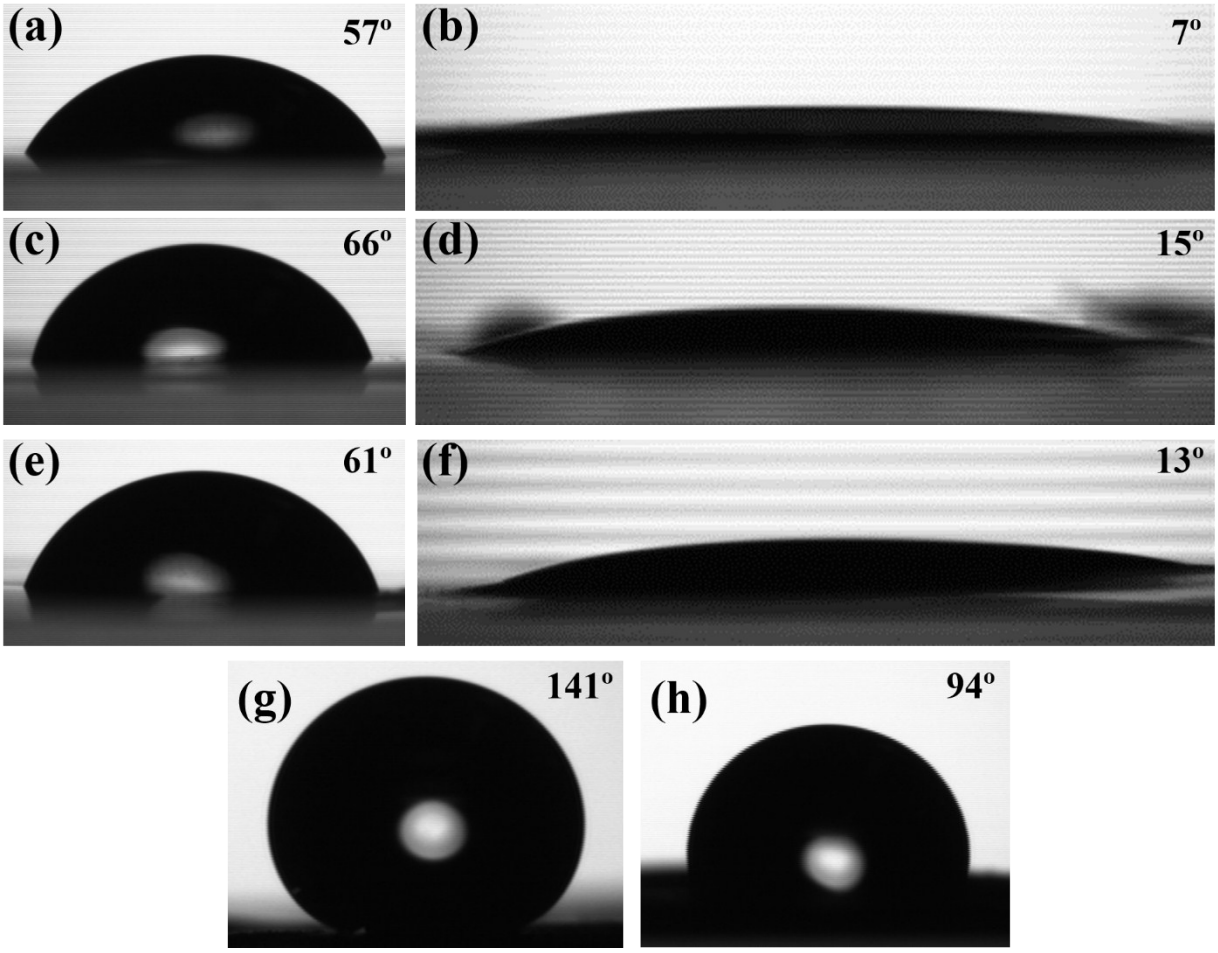

Fig. S4. Contact angles of (a) water on a CO_2 plasma-treated separator, (b) the electrolyte on a CO_2 plasma-treated separator, (c) water on an N_2 plasma-treated separator, (d) the electrolyte on an N_2 plasma-treated separator, (e) water on an O_2 plasma-treated separator, (f) the electrolyte on an O_2 plasma-treated separator, (g) water on a pristine carbon layer, (h) water on a CO_2 plasma-treated carbon layer.

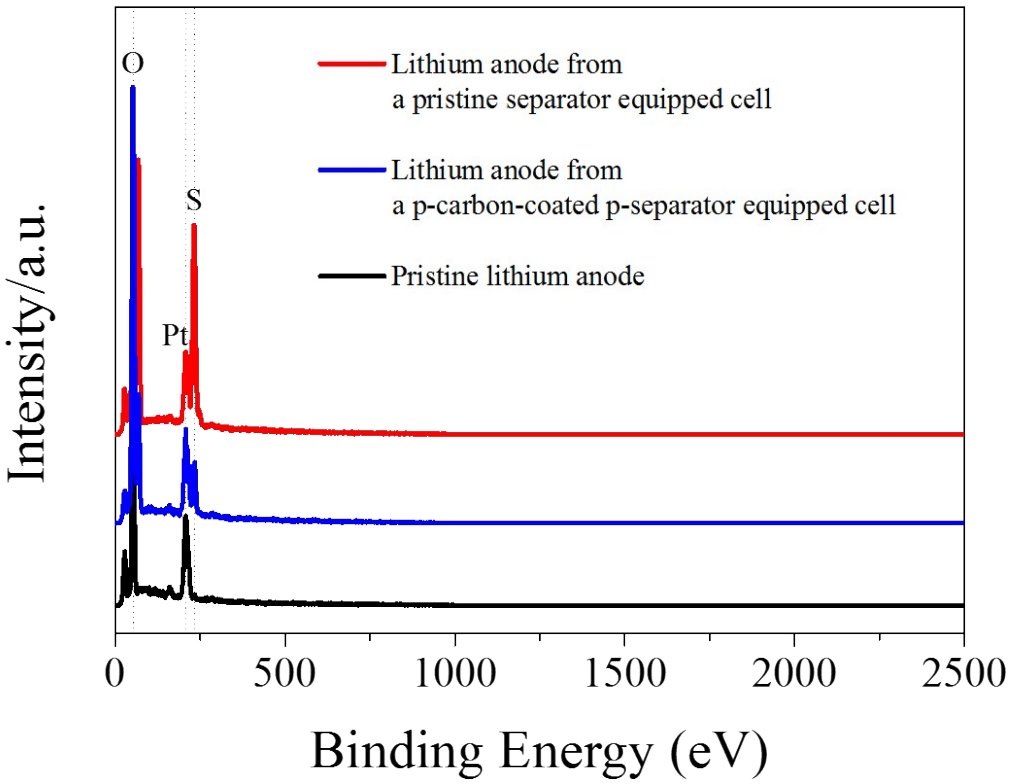

Fig. S5. Analysis of sulfur content in the anode side of the Li-S cell after 10 cycles using energy dispersive X-ray spectroscopy (EDS).

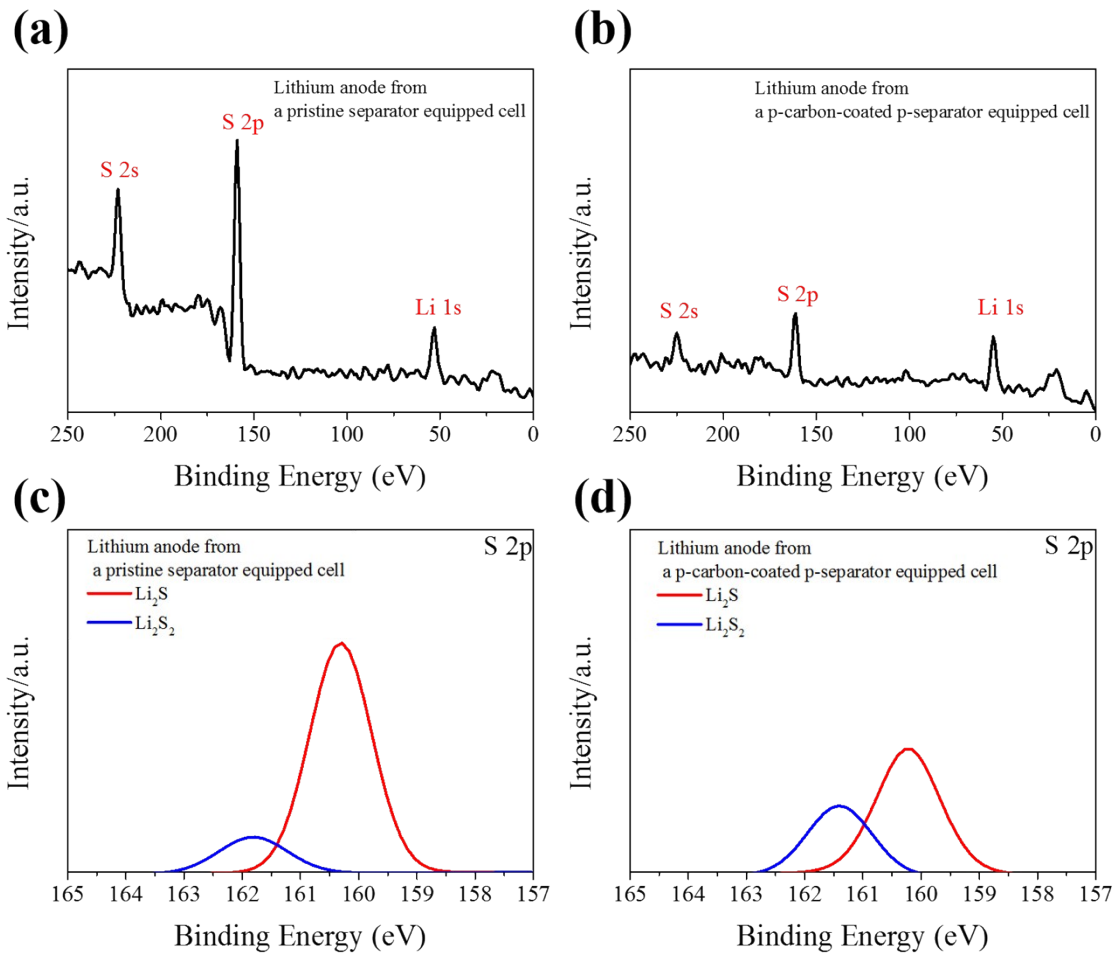

Fig. S6. XPS analysis of sulfur content in the anode side of the Li-S cell after 10 cycles: (a-b) wide spectra, (c-d) S 2p region.

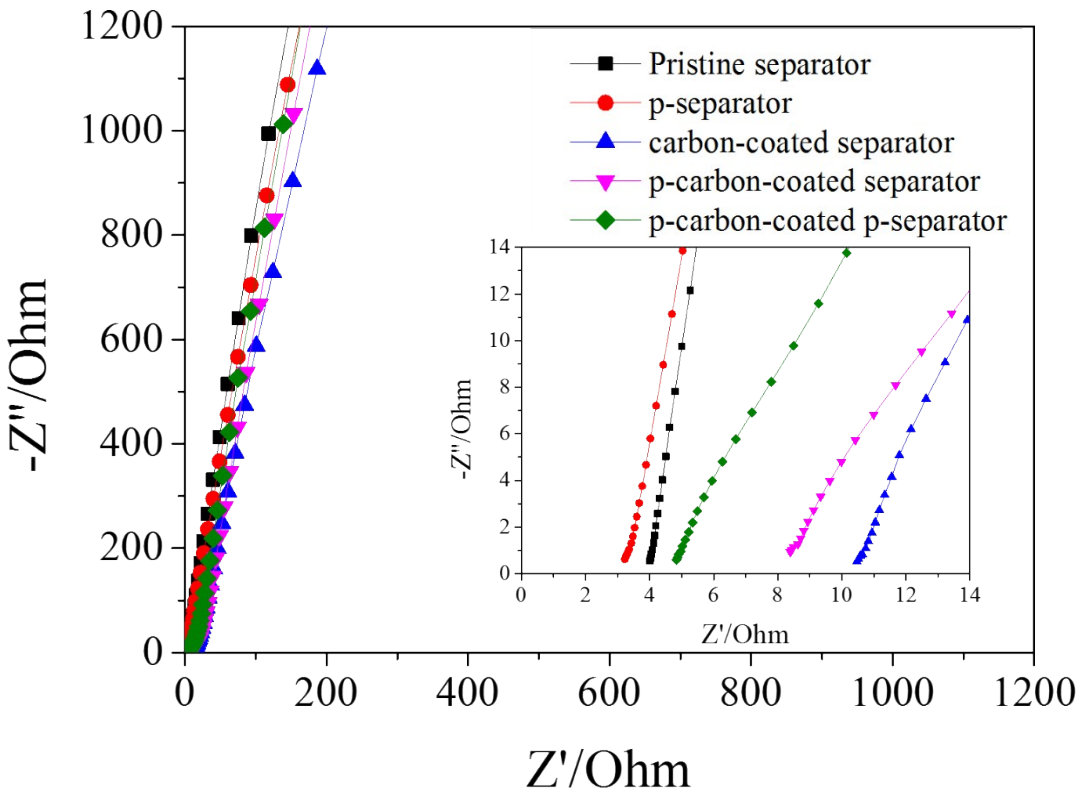

Fig. S7. Electrical impedance analyses showing the lithium ion conductivities of various functional separators.

Table S2. Permeation rates of polysulfide and lithium ion conductivities of the functional separators.

Sample	Permeation rate of polysulfide (mol cm^{-2} s^{-1})	Lithium ion conductivity (mS cm^{-1})
Pristine separator	1.24×10^{-8}	0.27
p-separator	1.16×10^{-8}	0.34
carbon-coated separator	2.10×10^{-9}	0.15
p-carbon-coated separator	1.54×10^{-9}	0.19
p-carbon-coated p-separator	1.79×10^{-10}	0.30

Table S3. Elemental analysis of sulfur and oxygen from the spectra of energy dispersive X-ray spectroscopy (EDS).

Sample	Atomic ratio (%)	
	O	S
Pristine lithium anode	98.41	1.59
Lithium anode from a pristine separator equipped cell after 10 cycles	75.35	24.62
Lithium anode from a p-carbon coated p-separator equipped cell after 10 cycles	92.54	7.46

Table S4. XPS analysis data comparing the area ratios of Li, O and S in the lithium anodes tested.

Sample	Area ratio (%)		
	Li 1s	O 1s	S 2p
Lithium anode from a pristine separator equipped cell after 10 cycles	50.56	37.56	11.88
Lithium anode from a p-carbon coated p-separator equipped cell after 10 cycles	64.28	33.35	2.37

Table S5. XPS analysis data comparing the relative amounts of Li_2S and Li_2S_2 in the anode sides of the cells employing a pristine and a p-carbon-coated p-separator, respectively.

Sample	Area ratio (%)	
	Li_2S	Li_2S_2
Lithium anode from a pristine separator equipped cell after 10 cycles	85.35	14.65
Lithium anode from a p-carbon coated p-separator equipped cell after 10 cycles	66.67	33.33

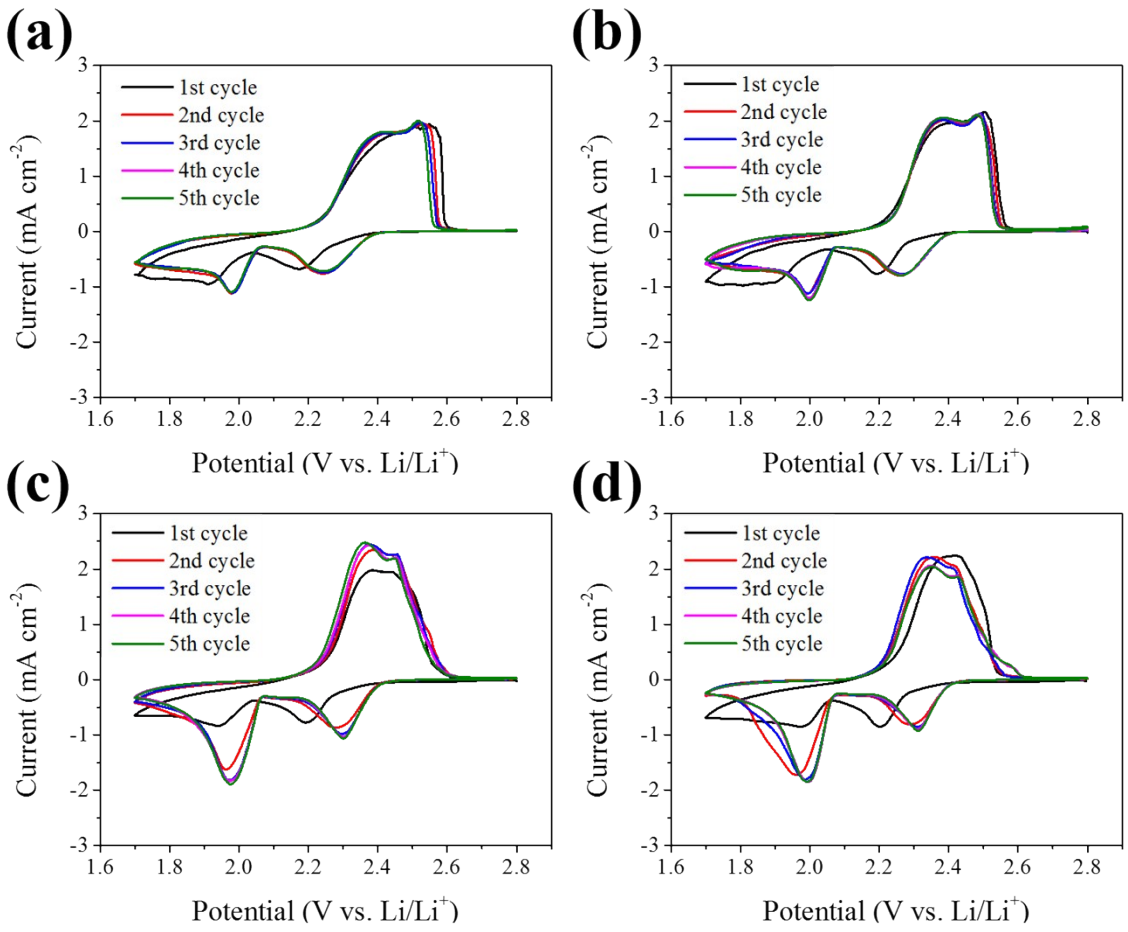

Fig. S8. CV curves of (a) a pristine separator, (b) a p-separator, (c) a carbon-coated separator, (d) a p-carbon-coated separator during the first five cycles at a scan rate of 0.1 mV s^{-1}.

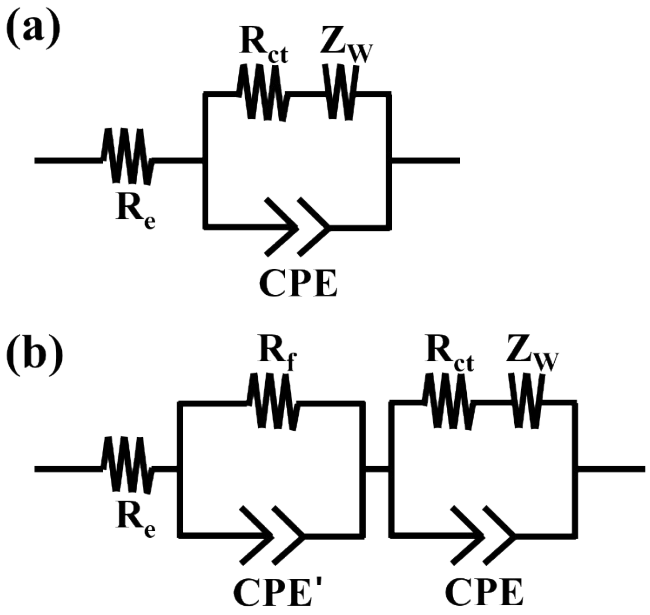

Fig. S9. The equivalent circuit models used for fitting the impedance spectra of the Li-S batteries employing (a) a bare separator and (b) a carbon-coated separator, respectively.

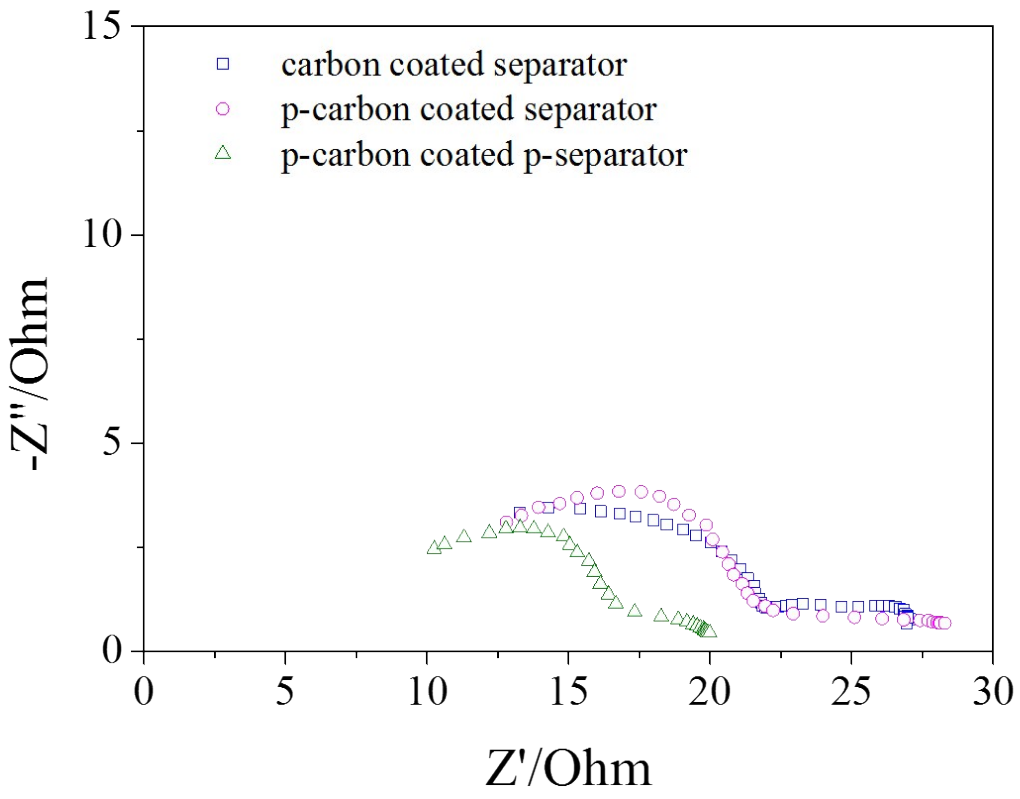

Fig. S10. Magnified Nyquist plots for the Li-S batteries employing carbon-coated separators in Fig. 8c.