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

Yolk-shell carbon microspheres with controlled yolk and void volumes and shell thickness and their application as a cathode material for Li-S batteries

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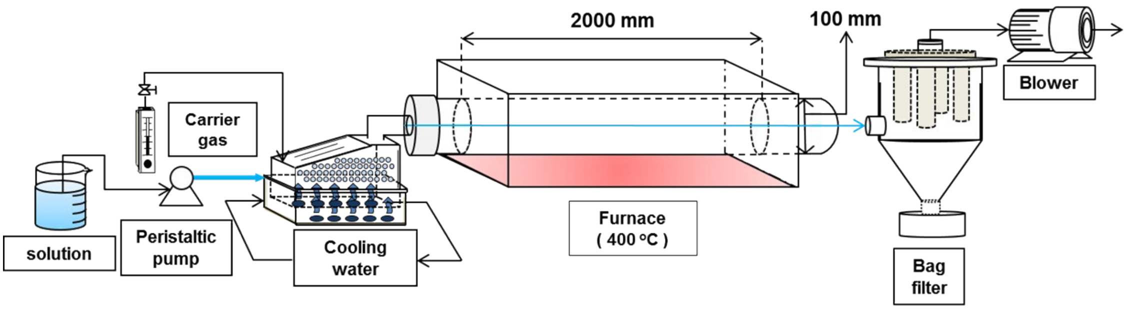

Fig. S1. Schematic diagram of the large-scale spray pyrolysis process applied in this study.

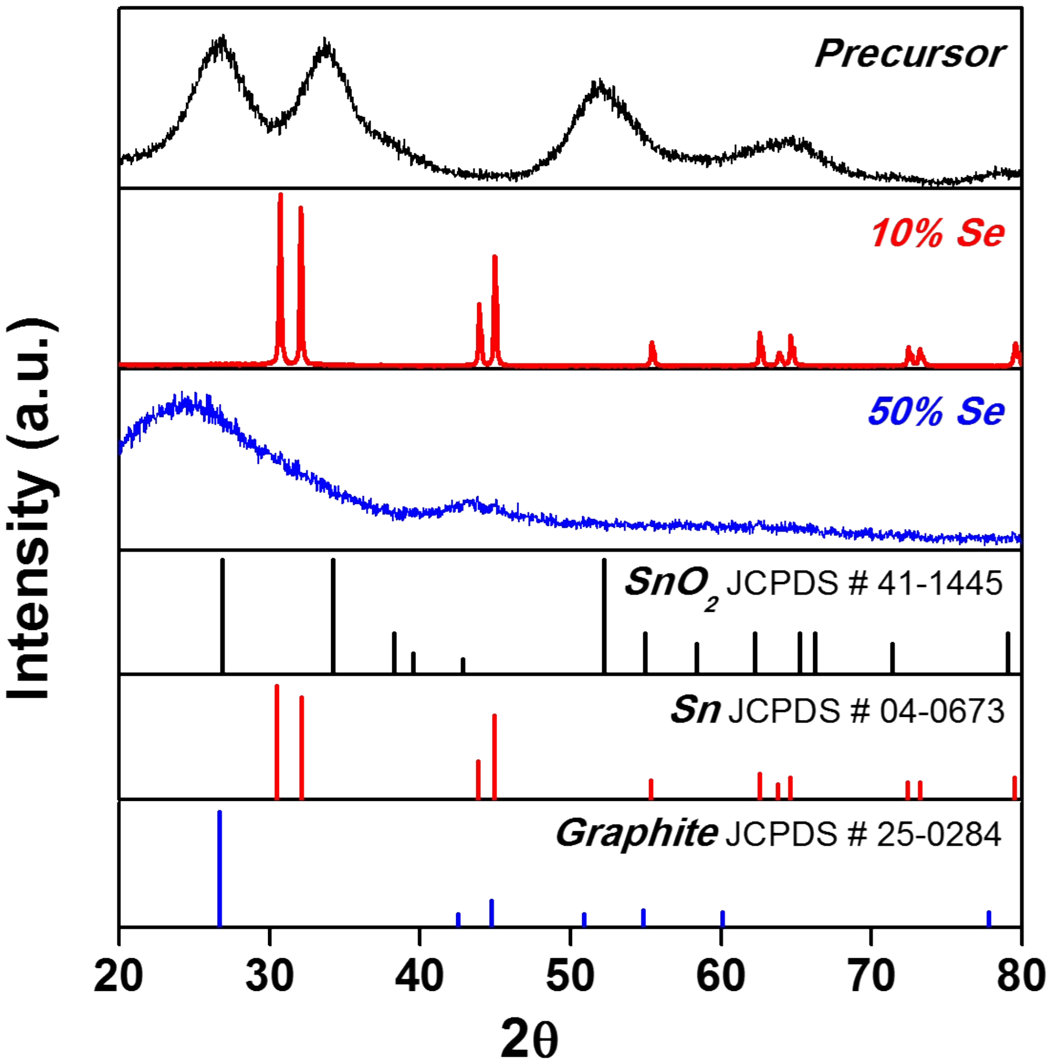

Fig. S2. XRD patterns of the SnO_2/carbon-carbon core-shell-structured microspheres prepared from the spray solution containing Sn oxalate and PVP before and after post-treatment with different quantities of Se.

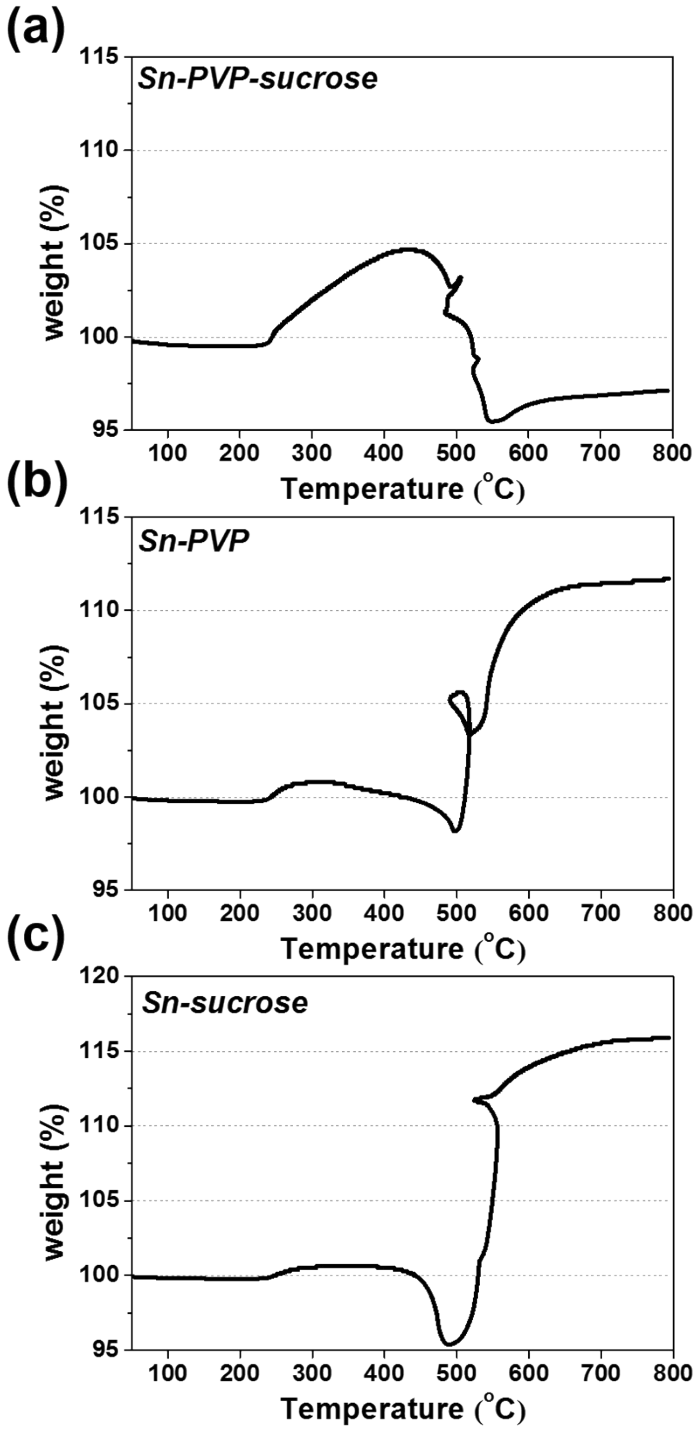

Fig. S3. TG curves of the Sn-C microspheres prepared from the spray solution with (a) both PVP and sucrose, (b) PVP alone, and (c) sucrose alone as carbon sources.

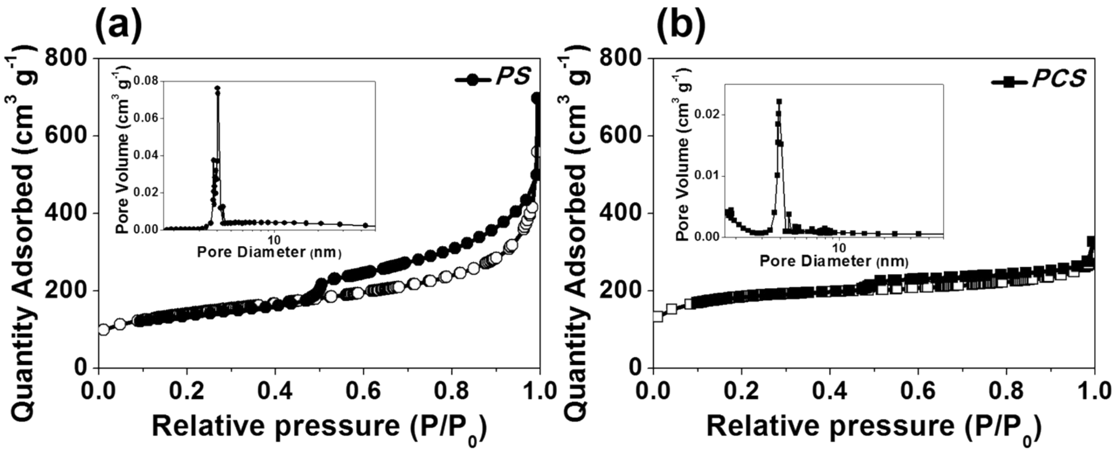

Fig. S4. Nitrogen adsorption and desorption isotherms and pore size distributions of the (a) PS and (b) PCS microspheres.

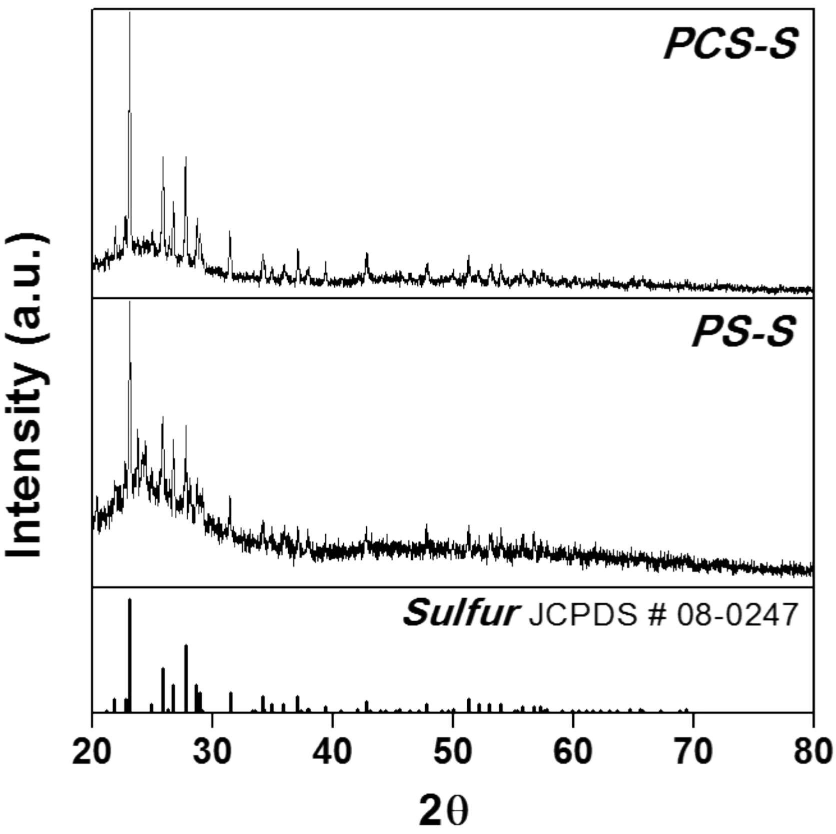

Fig. S5. XRD patterns of the PS-S and PCS-S microspheres.

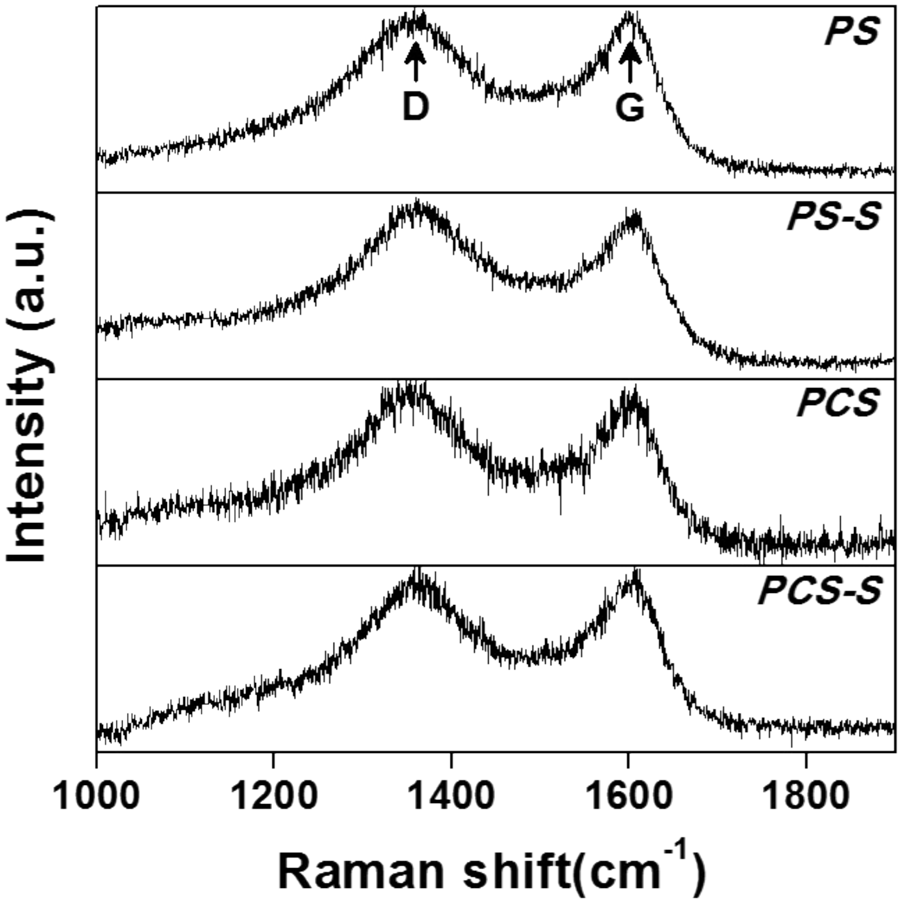

Fig. S6. Raman spectra of PS, PS-S, PCS, and PCS-S microspheres.

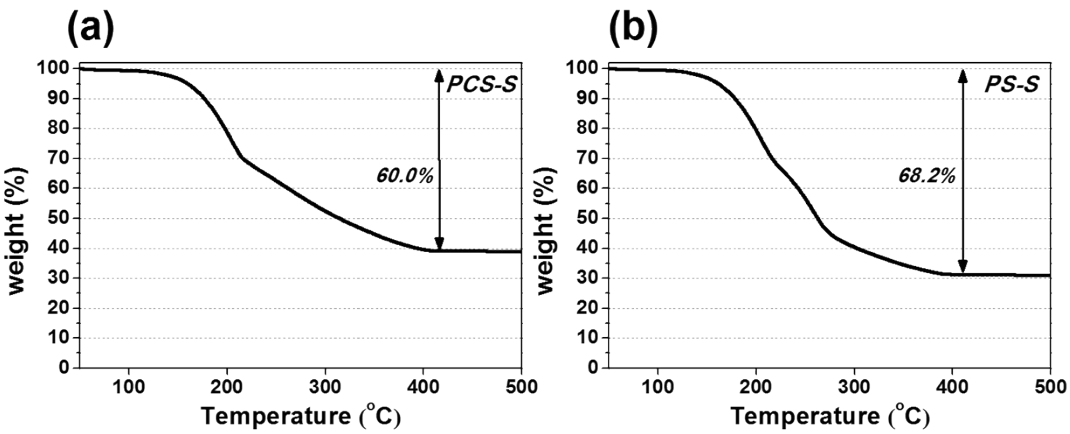

Fig. S7. TG curves of (a) PCS-S and (b) PS-S microspheres.

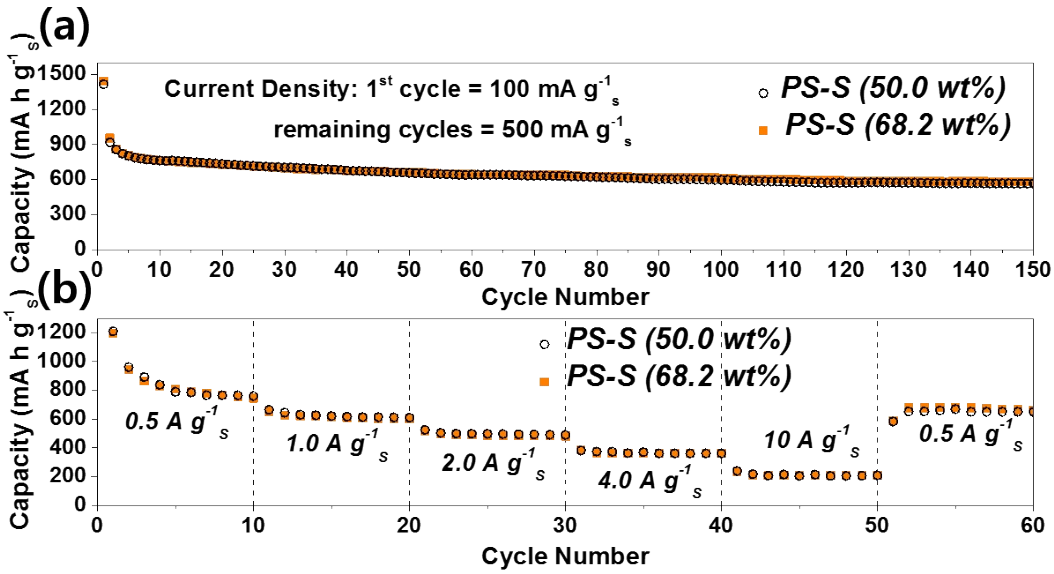

Fig. S8. Electrochemical properties of PS-S microspheres with 50.0 and 68.2 wt% sulfur: (a) cycling performances and (b) rate performances.

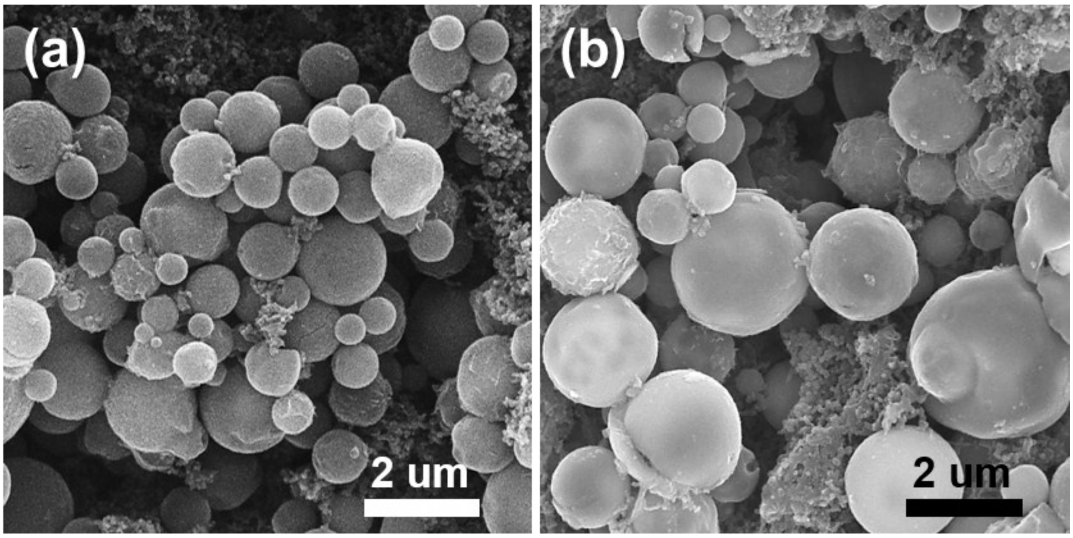

Fig. S9. Morphologies of the (a) PCS-S and (b) PS-S microspheres obtained after the 50th cycle.

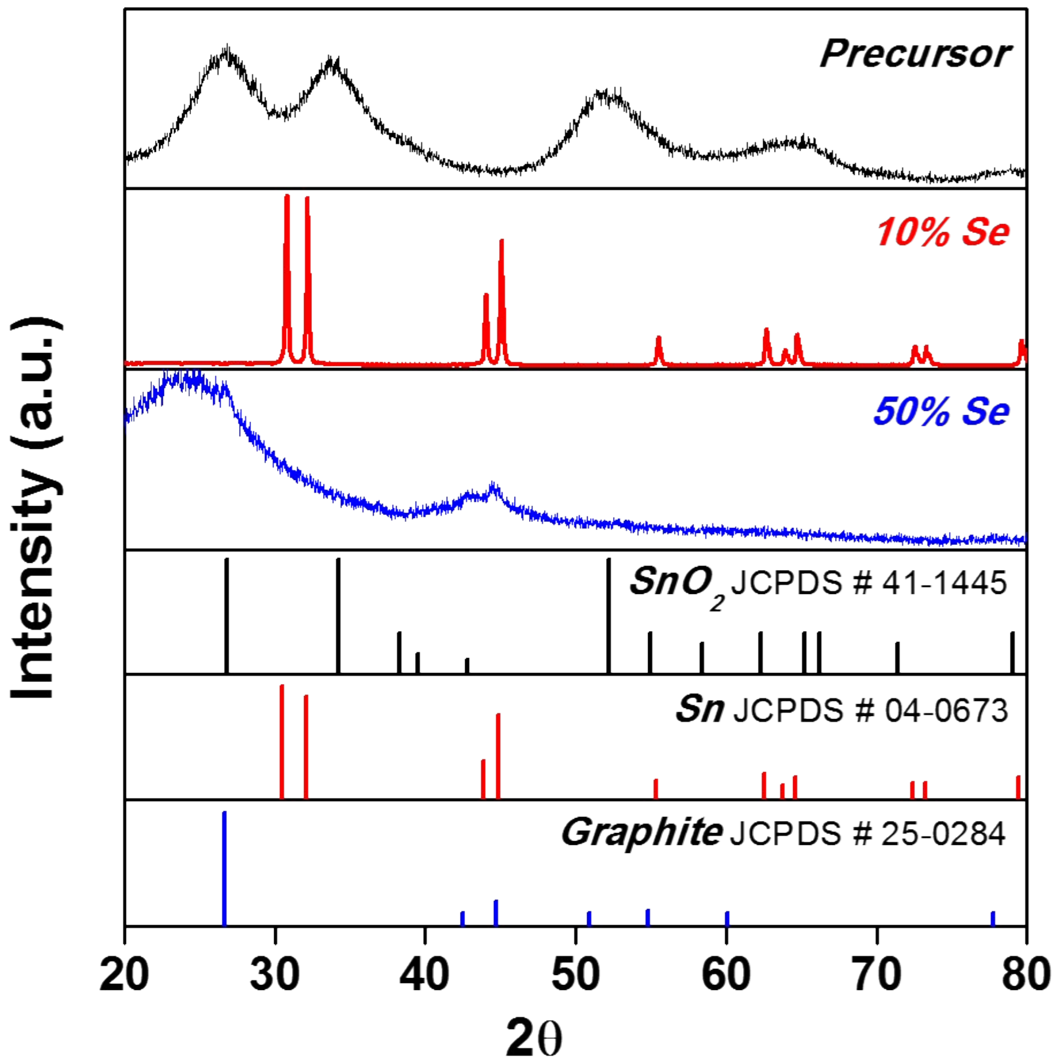

Fig. S10. XRD patterns of the SnO_2/carbon-carbon core-shell-structured microspheres prepared from the spray solution containing Sn oxalate, PVP, and sucrose before and after post-treatment with different quantities of Se.

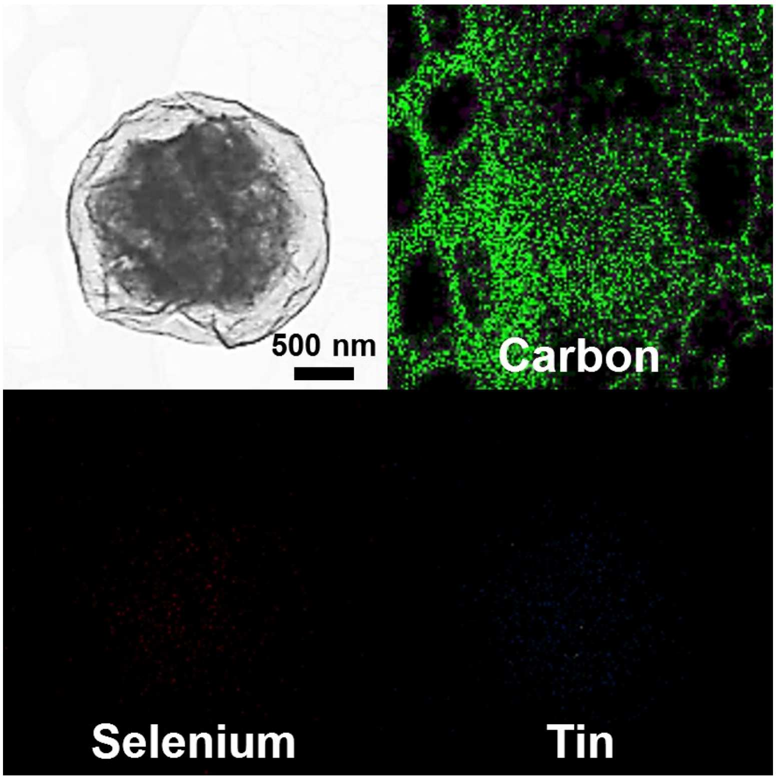

Fig. S11. TEM and dot-mapping images of the carbon yolk-shell microspheres prepared from the spray solution containing Sn oxalate, PVP, and sucrose.

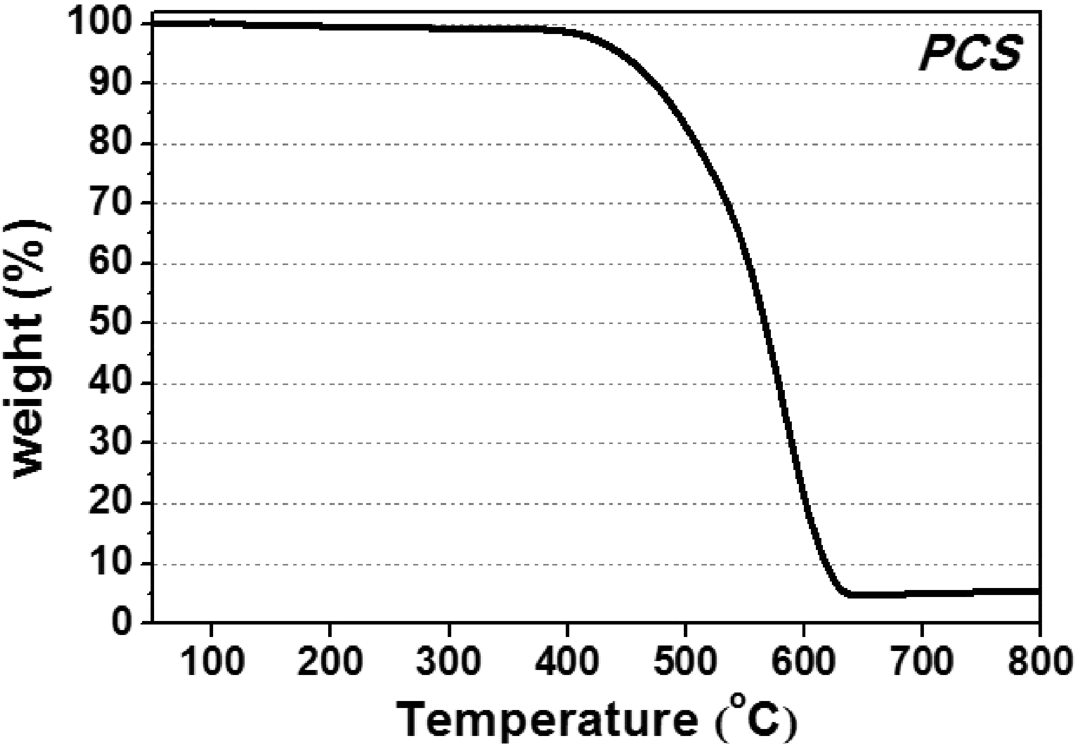

Fig. S12. TG curve of the carbon yolk-shell microspheres prepared from the spray solution containing Sn oxalate, PVP, and sucrose.

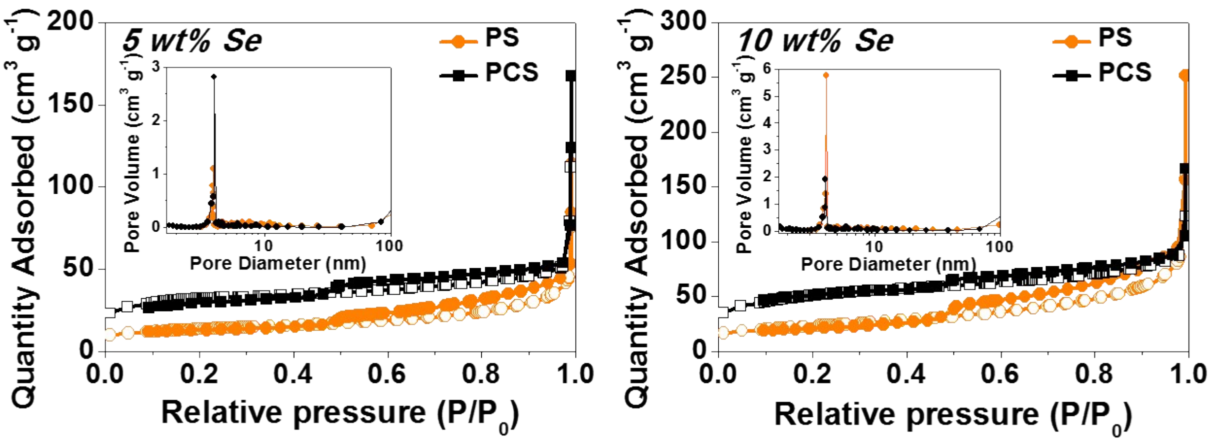

Fig. S13. Nitrogen adsorption and desorption isotherms of the SnO_2/carbon-carbon core-shell-structured microspheres after post-treatment with different quantities of Se.

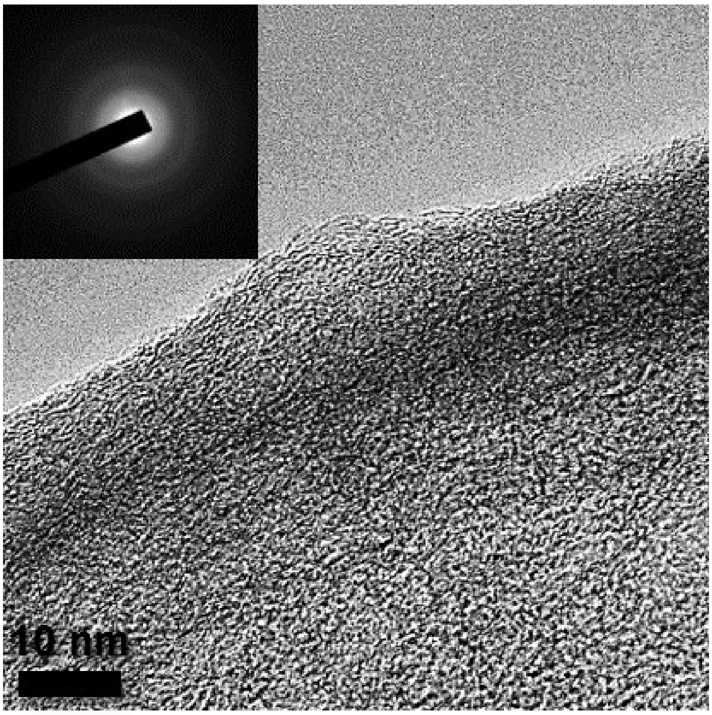

Fig. S14. High resolution TEM image and SAED pattern of the carbon yolk-shell microspheres prepared from the spray solution containing Sn oxalate and PVP.

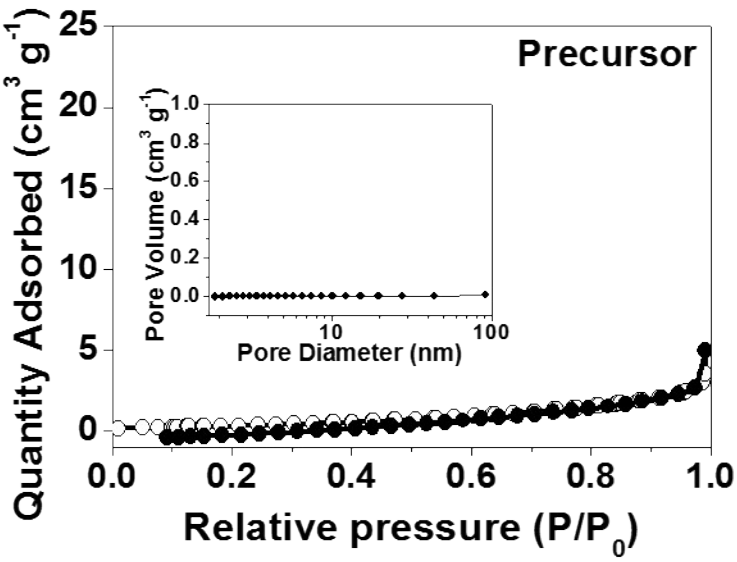

Fig. S15. Nitrogen adsorption and desorption isotherms of the SnO_2/carbon-carbon core-shell-structured microspheres prepared from the spray solution containing Sn oxalate, PVP, and sucrose.

Table S1. Li-ion storage properties of the carbon materials as cathode materials for Li-S batteries reported in the previous literatures.

Morphology [preparation method]	S content [wt%]	Current density	Initial C_{dis} [mA h g^{-1}]$_S$	Discharge capacity [mA h g^{-1}]$_S$	Cycle number	Ref.
hollow carbon nano sphere [direct carbonization]	61	837.5 mA g^{-1} (0.5 C)	1043	967	100	[22]
polydopamine-coated, nitrogen-doped, hollow carbon [silica template]	65	1003 (0.6 C)	740	630	600	[24]
multi-shelled hollow carbon nanospheres [aqueous emulsion approach]	86	167.3 mA g^{-1} (0.1 C)	1350	1250	200	[25]
hierarchical porous carbon [spray pyrolysis]	46	4020 mA g^{-1} (2.4 C)	700 (5th cycle)	539	500	[27]
porous hollow carbon spheres [template strategy]	50.2	83.75 mA g^{-1} (0.05 C)	1450	1357	50	[28]
hollow-in-hollow carbon spheres [template-assisted]	70	1000 mA g^{-1}	1080 (3rd cycle)	780	300	[38]
tube-in-tube carbon nanostructure [SiO_2 template]	71	2000 mA g^{-1}	659	647	200	[39]
double-shelled hollow carbon [hard template]	64	167.5 mA g^{-1} (0.1 C)	~1000	690	100	[40]
Yolk-shell carbon microspheres [spray pyrolysis]	60	500 mA g^{-1}	908 (2nd cycle)	600	150	This work