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

Supporting Information

CMK-5-encapsulated $MoSe_2$ Composite for Rechargeable Lithium-ion Batteries with Improved Electrochemical Performance

Cheng Zheng,[ab] Congrong Chen,[ab] Lin Chen[ab] and Mingdeng Wei*[ab]

[a] State Key Laboratory of Photocatalysis on Energy and Environmet, Fuzhou University, Fuzhou, Fujian 350002, China
[b] Institute of Advanced Energy Materials, Fuzhou University, Fuzhou, Fujian 350002, China

*Corresponding author: Mingdeng Wei
Tel./fax: +86-591-83753180
E-mail address: wei-mingdeng@fzu.edu.cn

Preparation of CMK-5

CMK-5 was prepared by using SBA-15 as hard template. Typically, 2 g of P123 ($EO_{20}PO_{70}EO_{20}$, Sigma-Aldrich) was added into 130 mL HCl solution (0.8 M) at 35 °C and was vigorously stirred till P123 was dissolved. Subsequently, 4.2 g of tetraethyl orthosilicate (TEOS) was added to the above solution rapidly. After being stirred for 5 min, the mixture was placed at a static condition at 35 °C for 24 h and at 130 °C for another 24 h. The SBA-15 template was obtained after the white precipitate was filtered, dried without washing, and calcined at 550 °C for 6 h. Then the SBA-15 powder was impregnated with aqueous solution of $AlCl_3$ (with a molar ratio of Si/Al = 20). After the solvent water was completely evaporated at room temperature, the samples were dried at 70 °C and calcined in air at 550 °C for 6 h. The aluminosilicate SBA-15 (Al-SBA-15) was incorporated with furfuryl alcohol (FA) at a mass ratio of 1:1.3 by incipient wetness infiltration. The FA/Al-SBA-15 mixture was then heated at 80 °C for 4 h and 150 °C for 8 h. Subsequently, the FA/Al-SBA-15 mixture was heated at 80 °C in vacuum condition for another 1 h. Then the dark brown powder was carbonized at 900 °C in Ar flow for 6 h. The CMK-5 was obtained after the removal of SBA-15 template by 5% HF acid at room temperature.

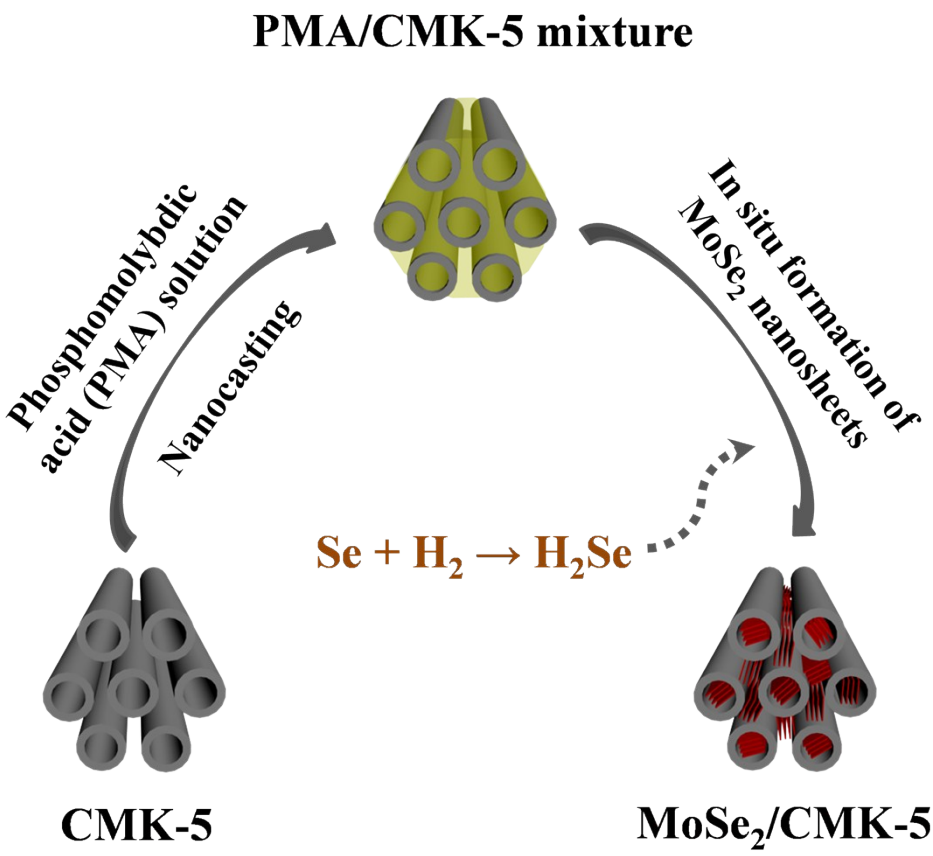

Fig. S1 Schematic illustration for the synthetic procedure of the $MoSe_2$/CMK-5 composite.

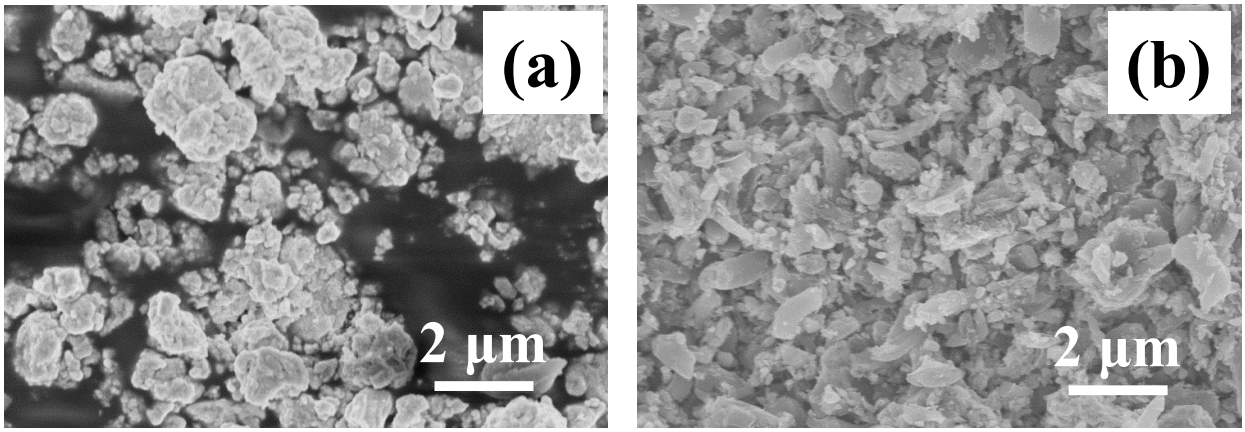

Fig. S2 SEM images of (a) bulk $MoSe_2$ and (b) mechanically mixed $MoSe_2$&CMK-5.

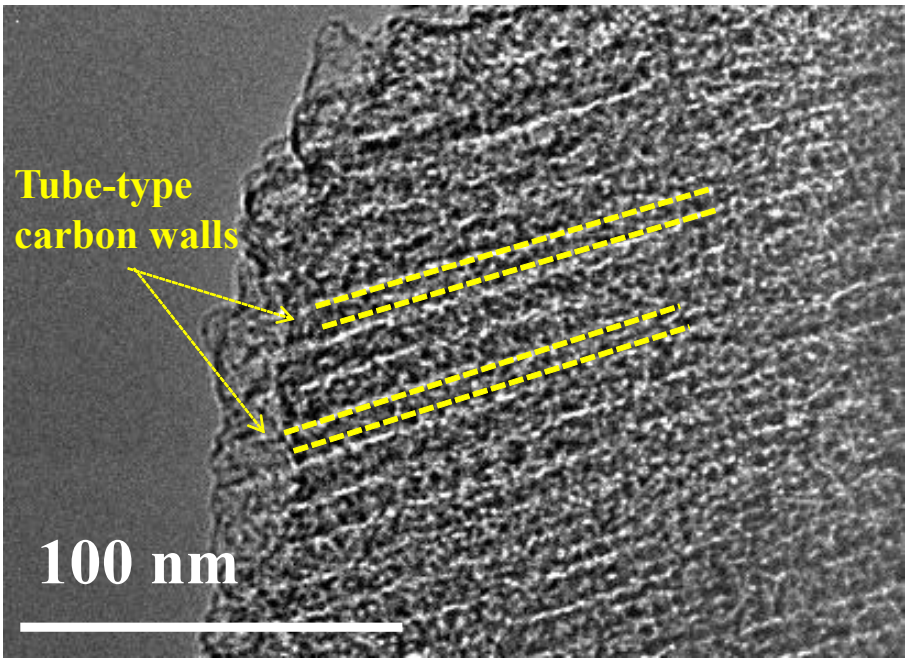

Fig. S3 Magnified TEM image of the CMK-5.

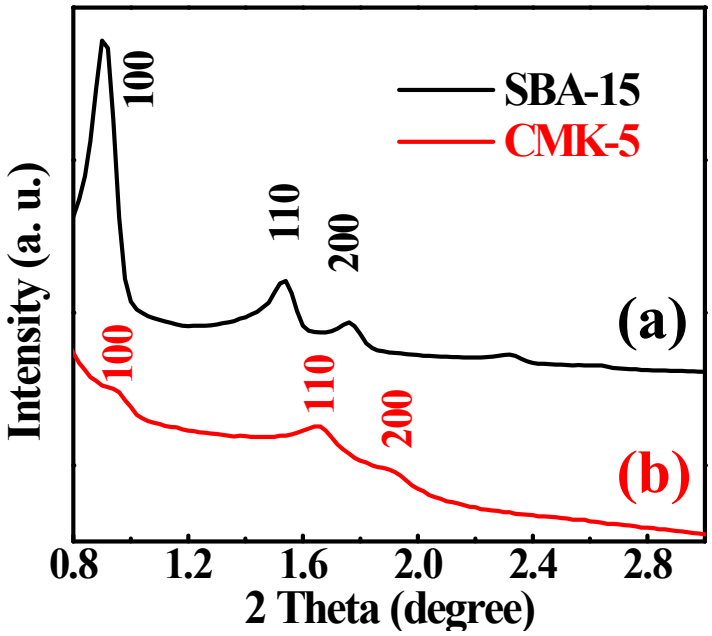

Fig. S4 Low-angle XRD patterns of the as-obtained (a) SBA-15 template (after calcination in air at 550 ^{o}C for 6 h) and (b) CMK-5.

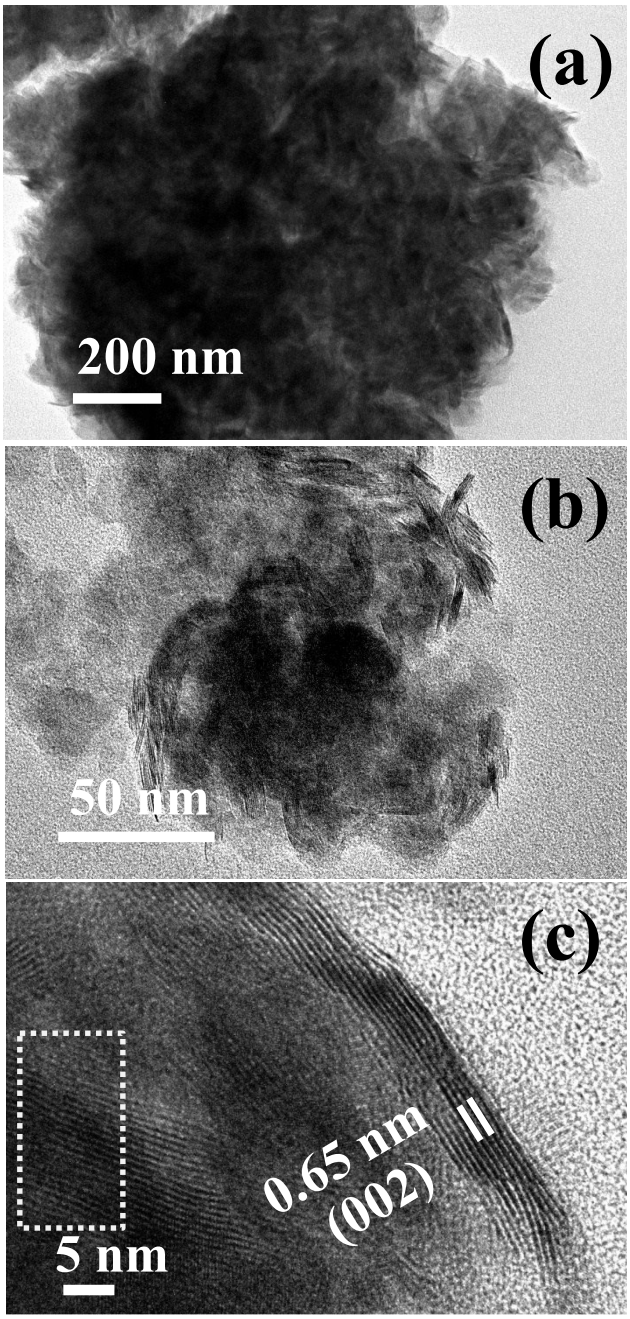

Fig. S5 (a, b) TEM images and (c) HRTEM image of bulk $MoSe_2$.

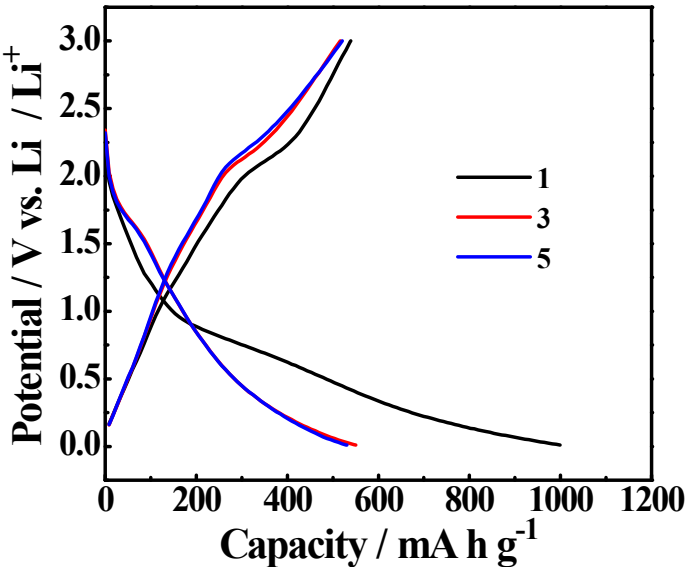

Fig. S6 Charge/discharge profiles of the $MoSe_2$/CMK-5 composite at the current density of 1000 mA g^{-1} within a voltage window of 0.01-3 V.

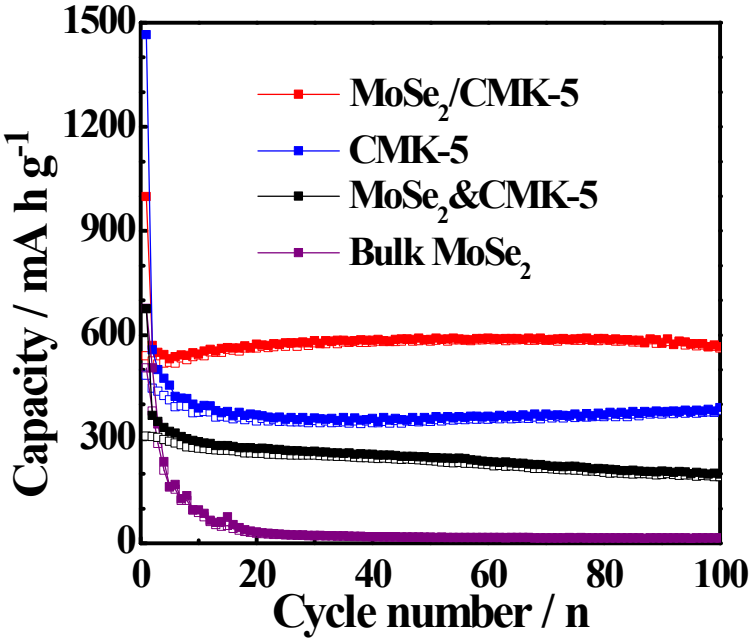

Fig. S7 Comparison of cycling performance of $MoSe_2$/CMK-5 composite, pure CMK-5 bulk $MoSe_2$ and $MoSe_2$&CMK-5 at a current density of 1000 mA g^{-1}.

Table S1. Comparison of the electrochemical properties of $MoSe_2$-based anode materials for LIBs.

Electrode material	High rate capacity/mA h g^{-1} (Current density/mA g^{-1})	Cycling performance		Ref.
		Current density/mA g^{-1}	Capacity/mA h g^{-1} (Cycle number)	
$MoSe_2$/CMK-5 composite	542 (2000)	100 1000 2000	788 (100) 567 (100) 451 (1000)	This work
$MoSe_2$/rGO	436 (2000)	100 1000 2000	714 (100) 637 (1000) 425 (1000)	1
3D $MoSe_2$/rGO foam	330 (844, 2C)	42.2, 0.1C 211, 0.5C	650 (50) 470 (600)	2
MoO_2@$MoSe_2$	485 (2000)	2000	520 (400)	3
$MoSe_2$/graphene hybrids	667 (1000)	100	1102 (100)	4
Sheet-like $MoSe_2$/C composites	450 (2000)	100	577 (50)	5
Mesoporous $MoSe_2$	372 (844, 2C)	21.1, 0.05C	630 (35)	6
$MoSe_2$@ PHCS	640 (3000)	1000	792 (100)	7
Coaxial-cable $MoSe_2$/C composites	524 (3000)	500	632 (100)	8
$MoSe_2$/rGO composite	750 (1000)	500	917 (100)	9

For most of the reported $MoSe_2$-based anode materials, the cycle numbers are 100 or less than 100, even though some of them exhibited high capacities over 790 mA h g^{-1}. [4, 7, 9] However, those with cycle numbers up to 500 are still rare. [1, 2] $MoSe_2$/rGO hybrids reported by Luo et al. [1] demonstrated a good cycling stability up to 1000 cycles, but the high rate capability was inferior. The 3D $MoSe_2$/rGO foam showed a good capacity retention for 600 cycles, [2] but the reversible capacity was dissatisfactory even cycled at a very low rate. Therefore, the $MoSe_2$/CMK-5 in this work demonstrates outstanding electrochemical properties considering the current rate and the cycling life.

References

1 Z. G. Luo, J. Zhou, L. R. Wang, G. Z. Fang, A. Q. Pan and S. Q. Liang, *J. Mater. Chem. A*, 2016, **4**, 15302-15308.
2 J. Yao, B. Liu, S. Ozden, J. Wu, S. Yang, M.-T. F. Rodrigues, K. Kalaga, P. Dong, P. Xiao, Y. Zhang, R. Vajtai and P. M. Ajayan, *Electrochim. Acta*, 2015, **176**, 103-111.
3 X. Zhao, J. Sui, F. Li, H. Fang, H. Wang, J. Li, W. Cai and G. Cao, *Nanoscale*, 2016, **8**, 17902-17910.
4 L. Ma, X. Zhou, L. Xu, X. Xu, L. Zhang and W. Chen, *J. Power Sources*, 2015, **285**, 274-280.
5 Y. Liu, M. Zhu and D. Chen, *J. Mater. Chem. A*, 2015, **3**, 11857-11862.
6 Y. Shi, C. Hua, B. Li, X. Fang, C. Yao, Y. Zhang, Y.-S. Hu, Z. Wang, L. Chen, D. Zhao and G. D. Stucky, *Adv. Funct. Mater.*, 2013, **23**, 1832-1838.
7 X. Yang, Z. Zhang, Y. Fu and Q. Li, *Nanoscale*, 2015, **7**, 10198-10203.
8 X. Yang, Z. Zhang and X. Shi, *J. Alloys Compd.*, 2016, **686**, 413-420.
9 Z. Zhang, Y. Fu, X. Yang, Y. Qu and Z. Zhang, *ChemNanoMat*, 2015, **1**, 409-414.