Interfacial electron modulation of MoS_2/black phosphorus heterostructure toward high-rate and high-energy density half/full sodium-ion batteries

Chenrui Zhang[a], Tingting Liang[c], Huilong Dong[a], Junjun Li[d], Junyu Shen[a], Wenjin Yang[e], Xuhong Wang[a,*], Hongbo Geng[a,*] Zhicheng Zhang[b,*]

[a]School of Materials Engineering, Changshu Institute of Technology, Changshu, Jiangsu 215500, China

[b]Tianjin Key Laboratory of Molecular Optoelectronic Sciences, Department of Chemistry, School of Science, Tianjin University, Tianjin 300072, China

[c]State Key Laboratory for Mechanical Behavior of Materials, Xi'an Jiaotong University, Xi'an 710049 China

[d]Tianjin Key Laboratory of Molecular Optoelectronic Sciences, Department of Chemistry, School of Science, Tianjin University, Tianjin 300072, China

[e]School of Materials and Energy, Guangdong University of Technology, Guangzhou 510006, China

E-mail address: wangxuhongjp@cslg.edu.cn (X. Wang), hbgeng@cslg.edu.cn (H. Geng), zczhang19@tju.edu.cn (Z. Zhang).

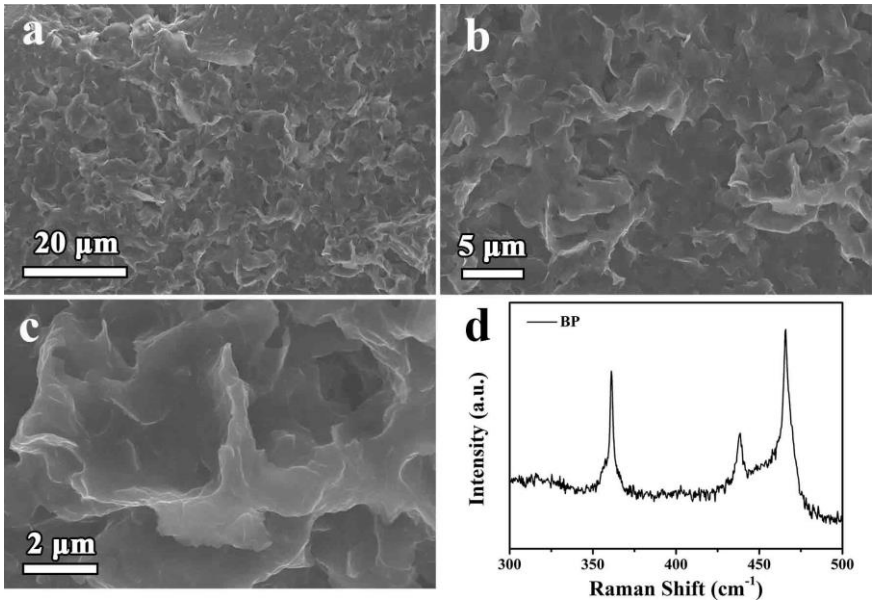

Fig. S1 (a-c) Various magnification SEM patterns of BP basic material. (d) Raman spectrum of BP basic material.

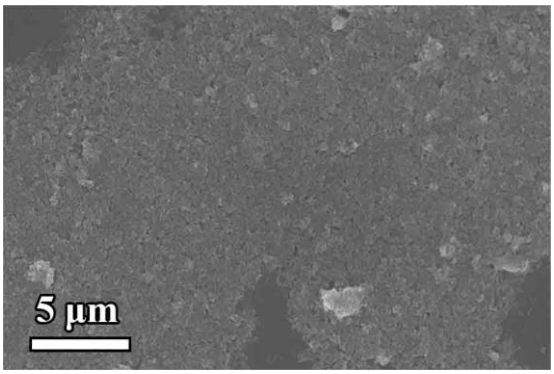

Fig. S2 The SEM pattern of MoS_2.

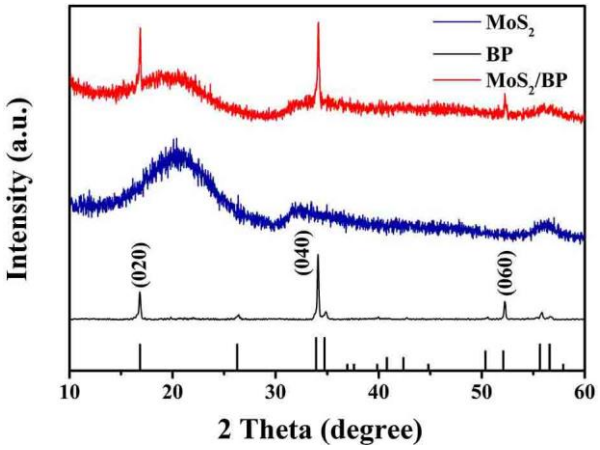

Fig. S3 (a) XRD patterns of MoS_2, BP and MoS_2/BP composite.

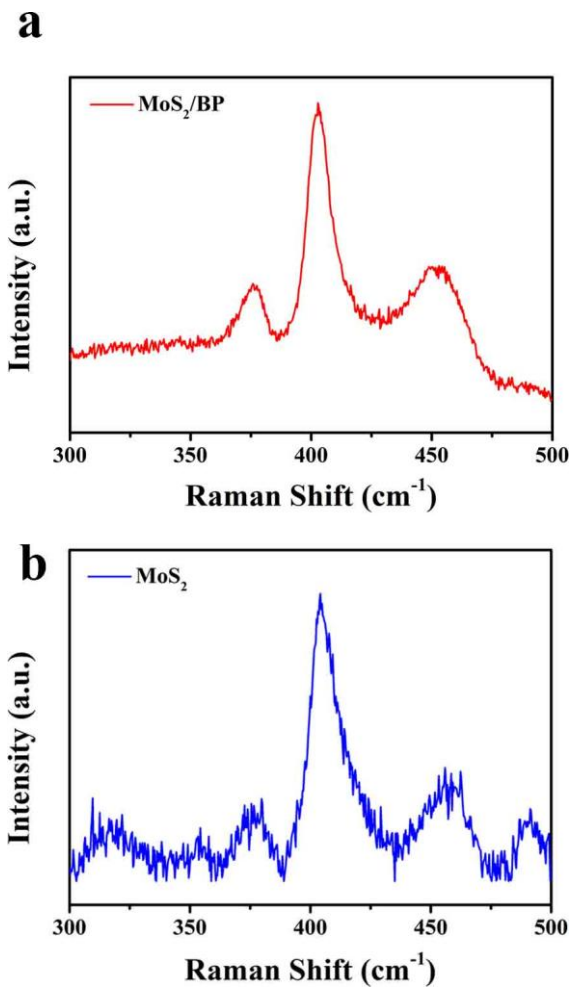

Fig. S4 (a) Raman spectrum of the MoS_2/BP composite and (b) MoS_2 basic material.

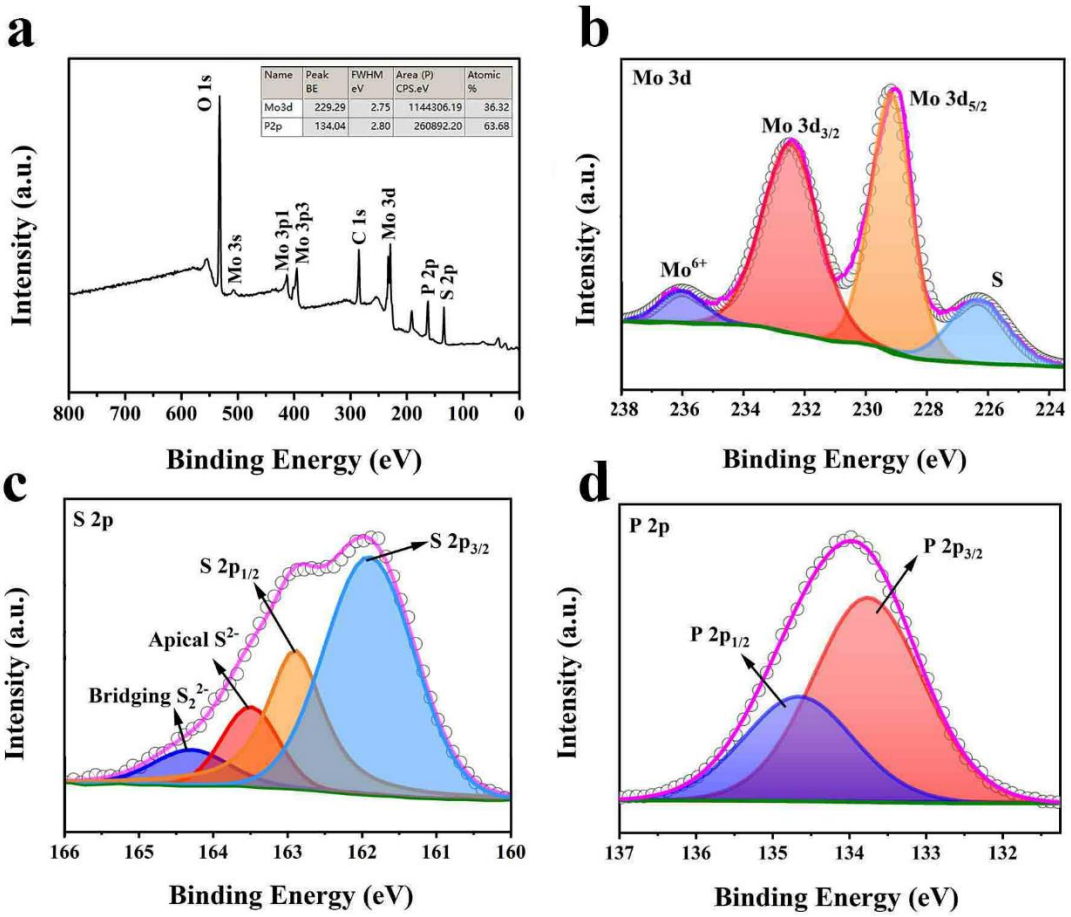

Fig. S5 (a) XPS survey and the high-resolution XPS spectra of (b) Mo 3d, (c) S 2p and (d) P 2p of the MoS_2/BP composite.

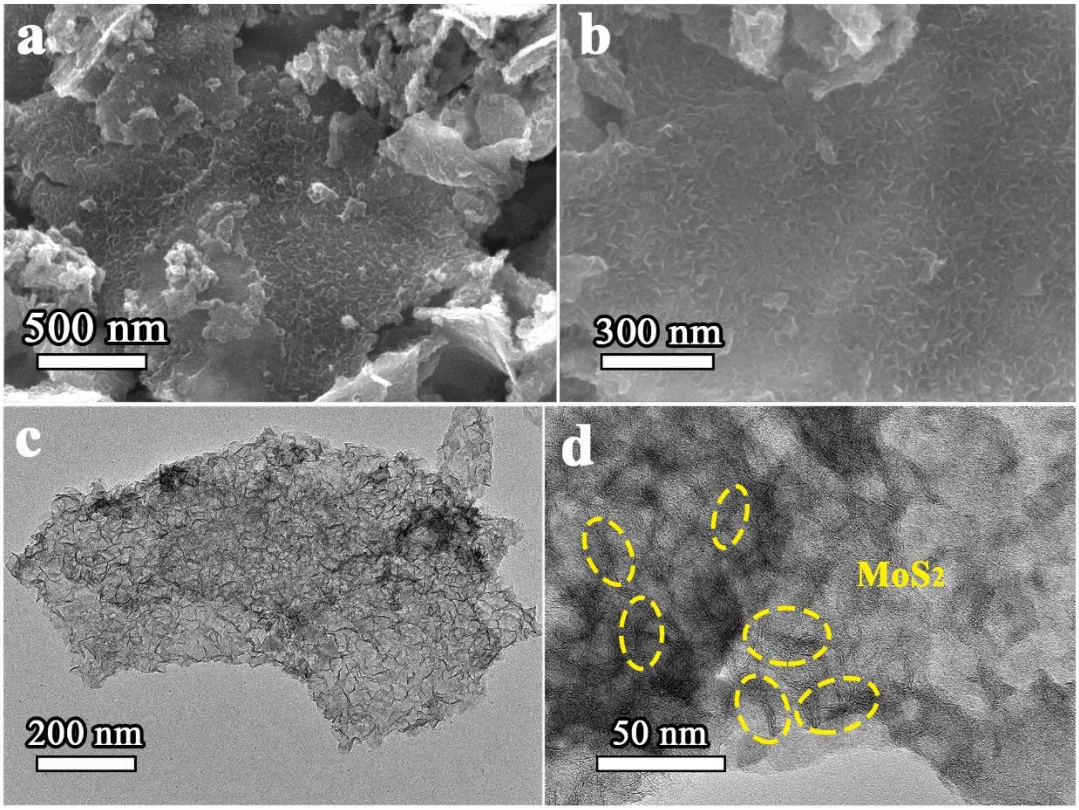

Fig. S6 (a, b) Low- and high-magnification SEM patterns of the MoS_2/BP composite. (c, d) Various magnification TEM and HRTEM pictures of the MoS_2/BP composite.

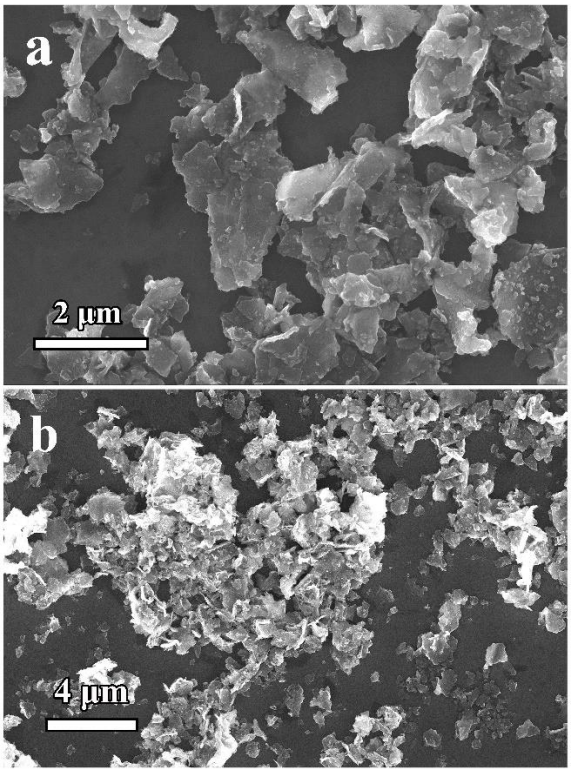

Fig. S7 (a), (b) Other magnifications SEM patterns of the MoS_2/BP composite.

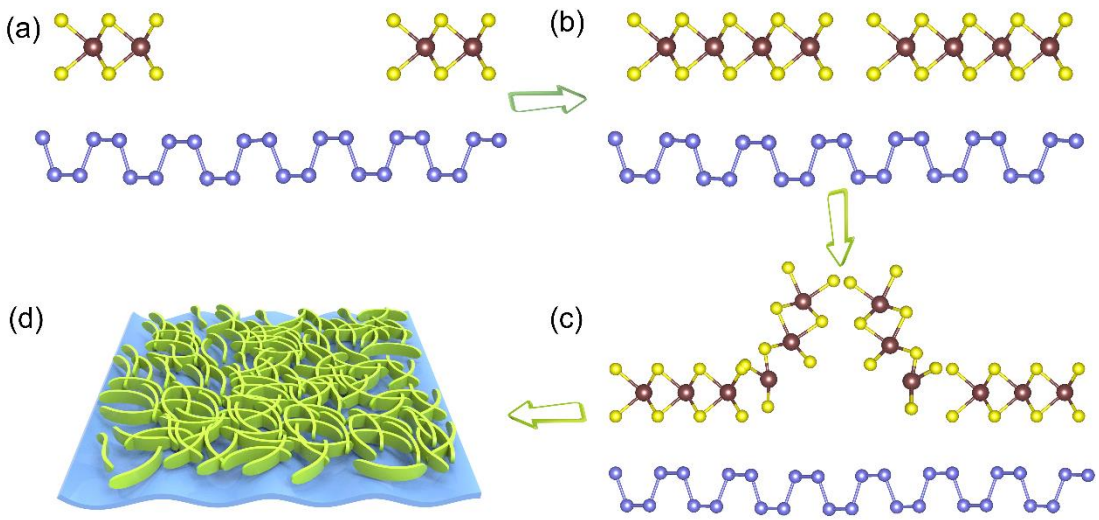

Fig. S8 Schematic diagram of the growth process of vertical MoS_2 nanosheets on BP: (a) nucleation, (b) diffusion, (c) forming arch structure, and (d) model of MoS_2/BP heterostructure.

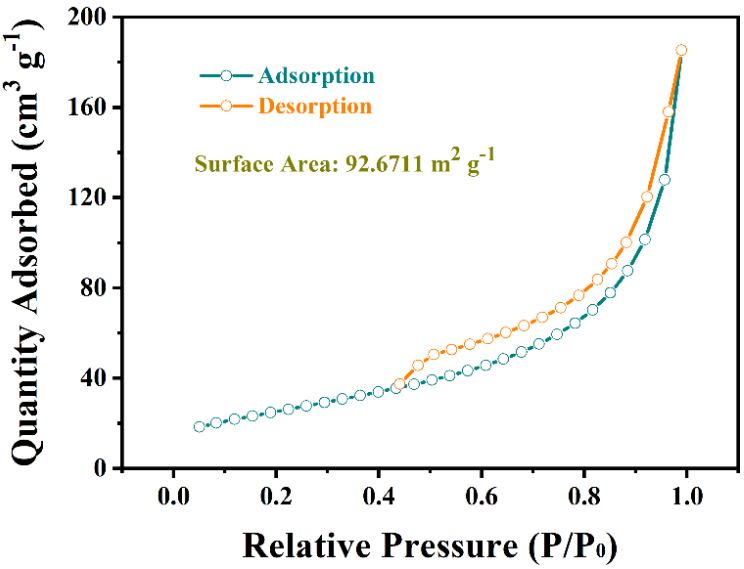

Fig. S9. The nitrogen adsorption-desorption isotherms curve of MoS_2/BP composite.

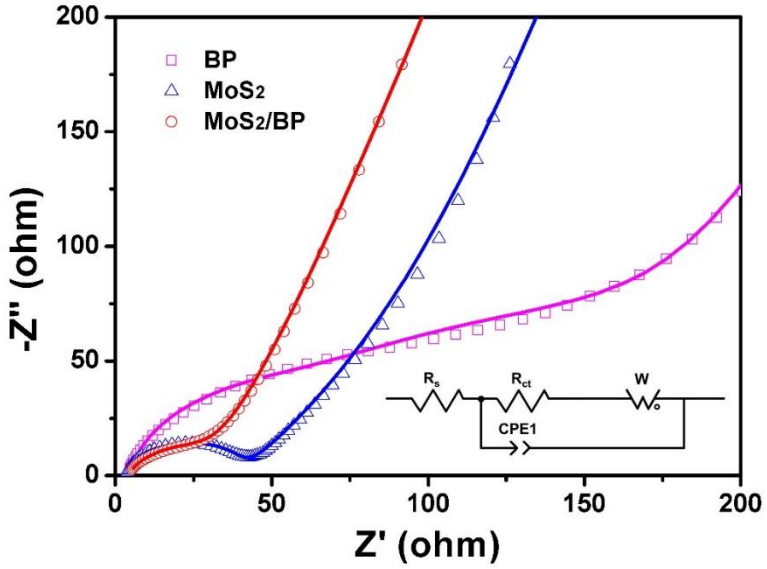

Fig. S10 Nyquist plots of the MoS_2, BP and MoS_2/BP electrodes. The inset is corresponding equivalent circuit. R_s is the ohmic resistance, R_{ct} is the charge transfer resistance, CPE_1 is the constant phase element, and W is the Warburg impedance.

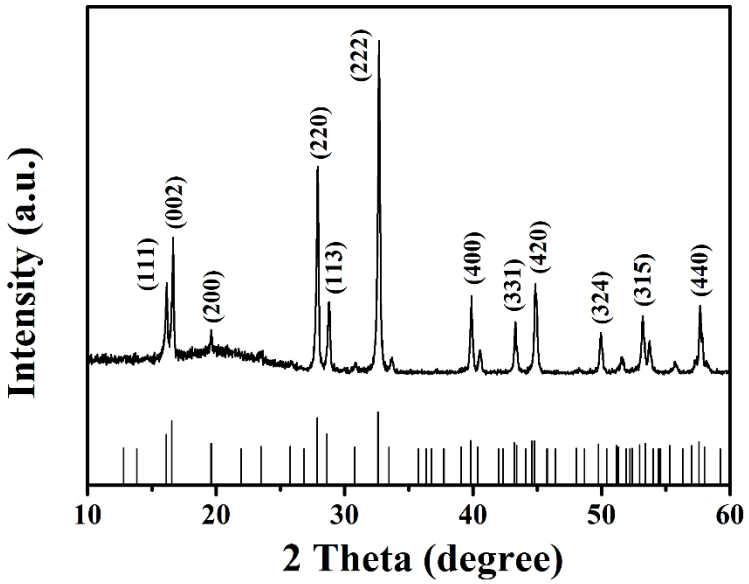

Fig. S11 The XRD pattern of the $Na_3V_2(PO_4)_2O_2F$ cathode material.