Constructing SnO_2-$MoSe_2$ heterojunction nanoflowers as high-rate and ultrastable anodes for sodium-ion half/full batteries

Shengkai Li[a], Haiyan Zhang[a,*], Shangshang Zhang[a], Yan Wan[a]

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

Experimental section

Synthesis of Sn-Mo nanoparticle precursor

In a typical synthesis, 0.3g CTAB (DaMao Co., China) was dissolved in 800 mL deionized water. 0.3 mol of Na_2MoO_4 (DaMao Co., China) and 0.3 mol of $SnCl_2 \cdot 2H_2O$ (DaMao Co., China) were sequentially added to the CTAB solution. Then co-precipitation synthesis was used at 40 °C for 6 h. After three suction filtration and water washing, the Sn-Mo nanoparticle precursor was obtained by freeze-dried.

Synthesis of SnO_2-$MoSe_2$ heterojunction nanoflowers

The 0.15 g Sn-Mo precursor and 0.15 g of Se (Innochem Co., China) powder were scattered into 70 mL of deionized water and then stirred vigorously for 2 h. 10 mL of $N_2H_4 \cdot H_2O$ (50%, Innochem Co., China) was added dropwise into the above suspension under vigorous stirring, the mixture was poured into an autoclave (100 mL) and reacted at 180 °C for 24 h. After the reaction, the precipitate was washed three times with deionized water and absolute ethanol. Then, SnO_2-$MoSe_2$ heterojunction nanoflowers were dried under vacuum at 60 °C for 12 h. In addition, SnO_2 and $MoSe_2$ were prepared by the same method.

* Corresponding author. E-mail: hyzhang@gdut.edu.cn (Haiyan Zhang)

Materials characterization

The crystal structures of the obtained active materials and electrode sheets were analyzed by X-ray diffraction (XRD, D/MAX-UItima IV). The microscopic morphology, lattice spacing and elemental distribution of the materials were analyzed by field emission scanning electron microscopy (FESEM, Hitachi/ SU8220) and high-resolution transmission electron microscopy (TEM and HRTEM, Talos F200S). The X-ray photoelectron spectroscopy (XPS, ESCALAB 250Xi) was employed to analyze the compositions of the samples. Emmett and Teller (BET, ASAP2460, Micromeritics) surface area was measured by using N_2 adsorption apparatus.

Electrochemical measurements

The CR2032 coin-type cells were assembled in the glovebox (H_2O and $O_2 < 0.01$ ppm). Electrode slurry was prepared by mixing the mass ratio of active material (7), Ketjen black (1.5) and polyvinylidene fluoride (PVDF) (1.5) in N-methyl-pyrrolidone. The slurry was then uniformly applied to copper foil and dried at 80 °C overnight, and finally cut into discs (d = 10 mm). A thin Na plate was used as counter electrode. The glass fiber filter (Whatman GF/A) separator was used as separator and 1 M $NaPF_6$ in diglyme (100%) was used as electrolyte. For the constructed full cell, commercial NVP (Innochem Co., China) was used as the cathode, respectively. Electrochemical performances of the batteries were investigated on Land battery tester (Wuhan LAND Corporation, China). Cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) curves were tested with an electrochemical workstation (CHI660E).

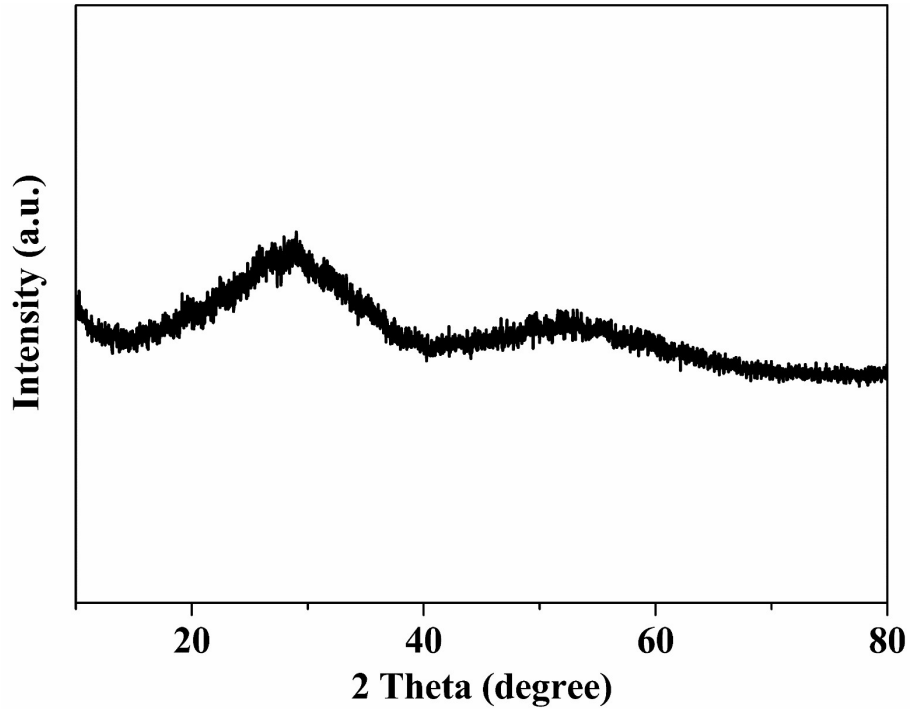

Fig. S1. XRD pattern of Sn-Mo precursor.

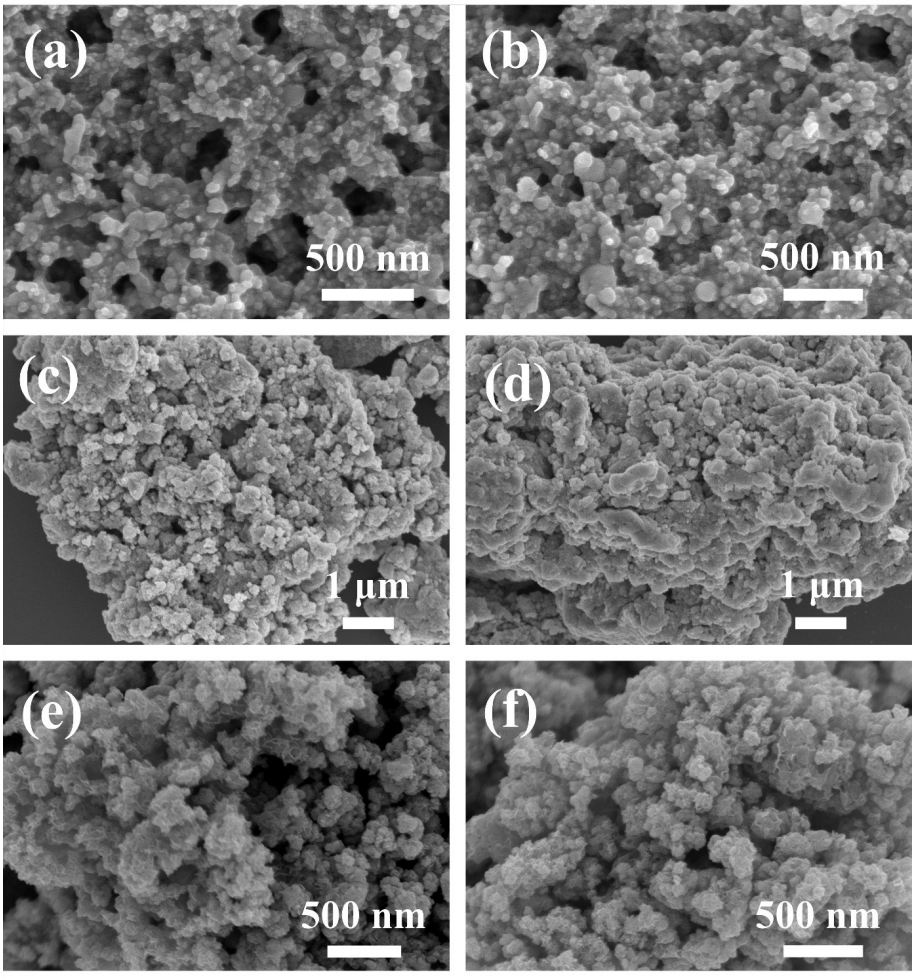

Fig. S2. SEM images of (a, b) Sn-Mo precursor; (c, d) SnO_2; (e, f) $MoSe_2$.

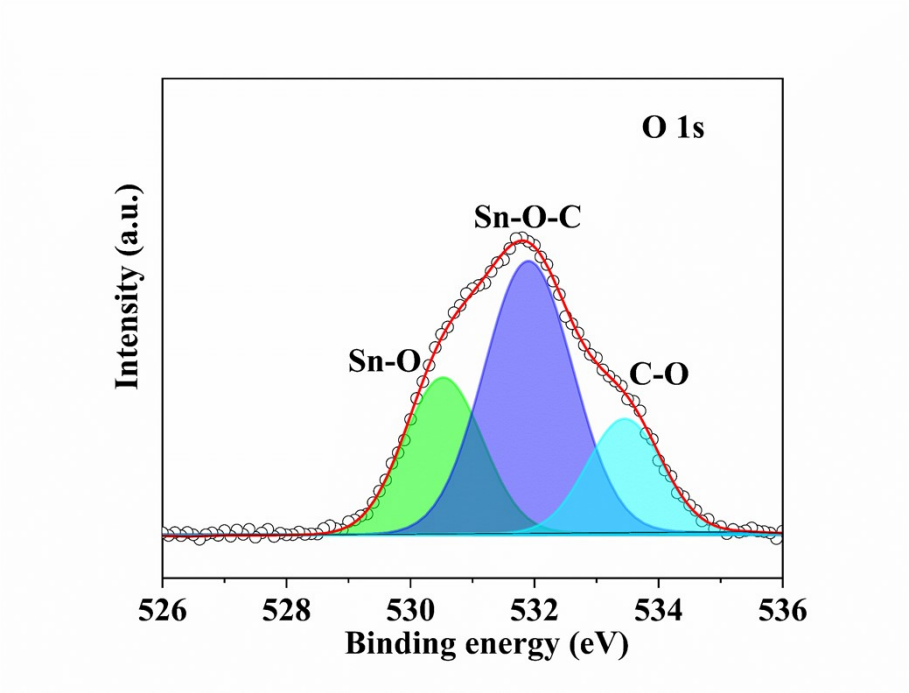

Fig. S3. High-resolution XPS spectra for O 1s.

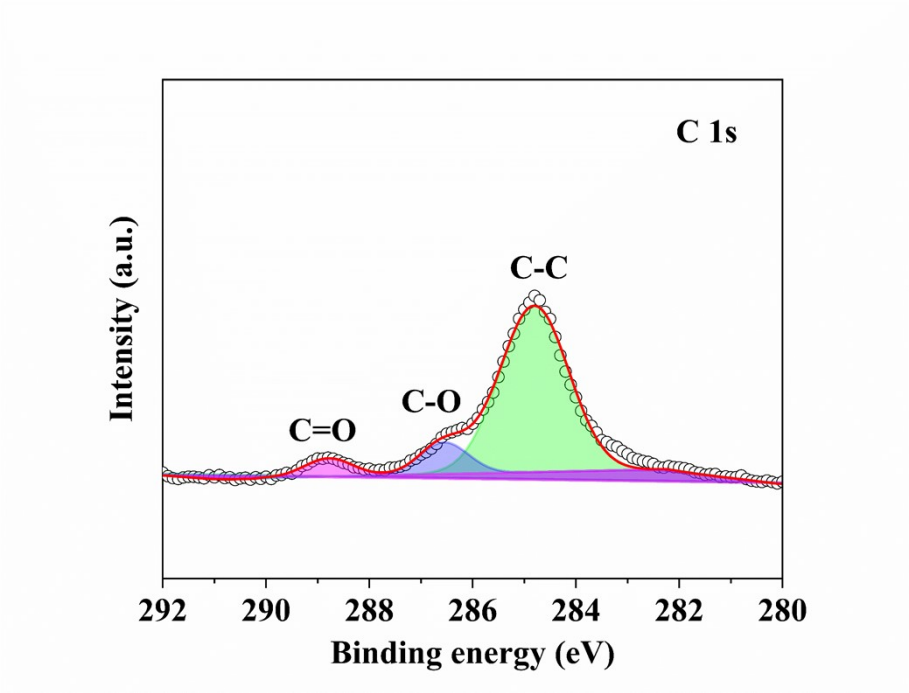

Fig. S4. High-resolution XPS spectra for C 1s.

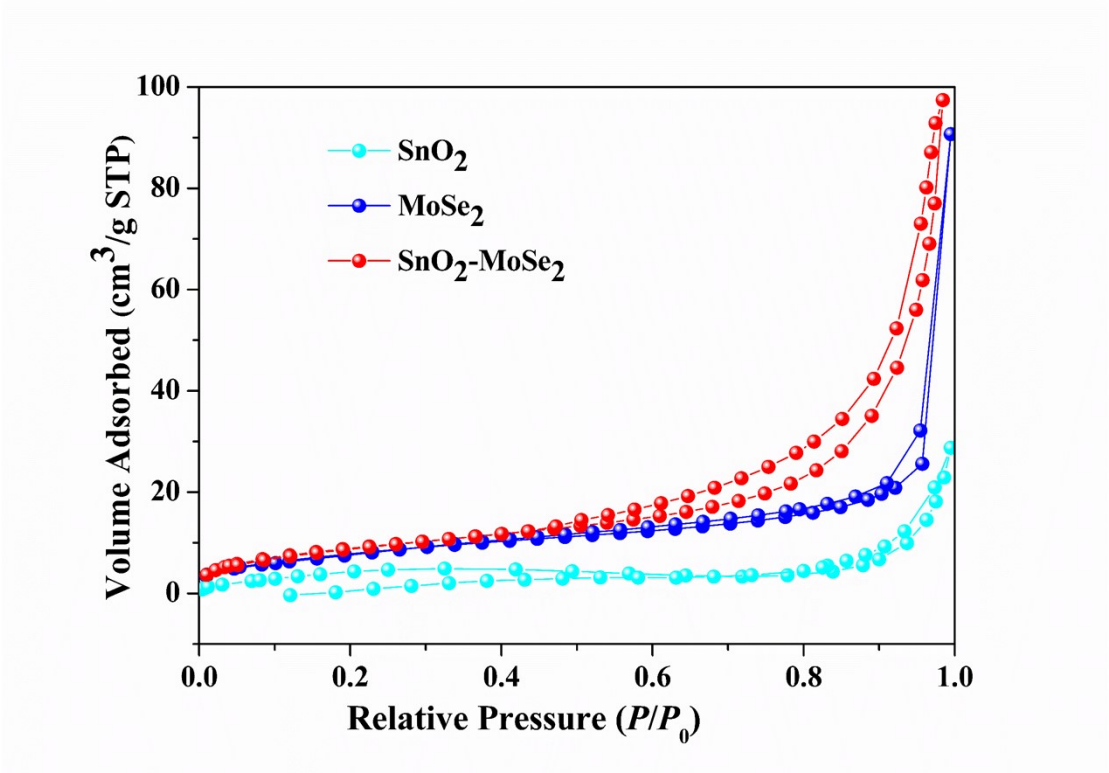

Fig. S5. N_2 adsorption/desorption isotherm curves.

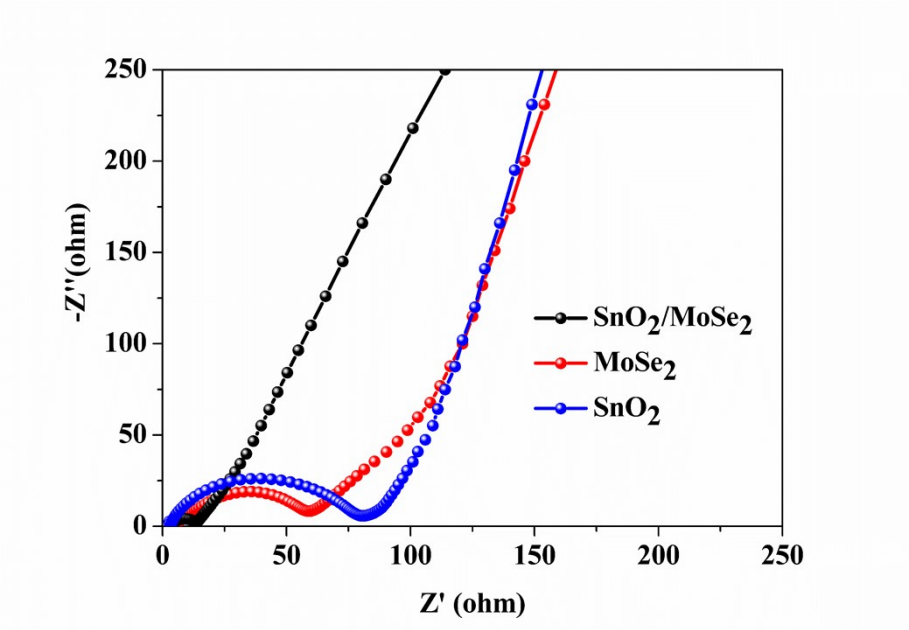

Fig. S6. The Nyquist plots of $SnO_2/MoSe_2$, SnO_2 and $MoSe_2$.

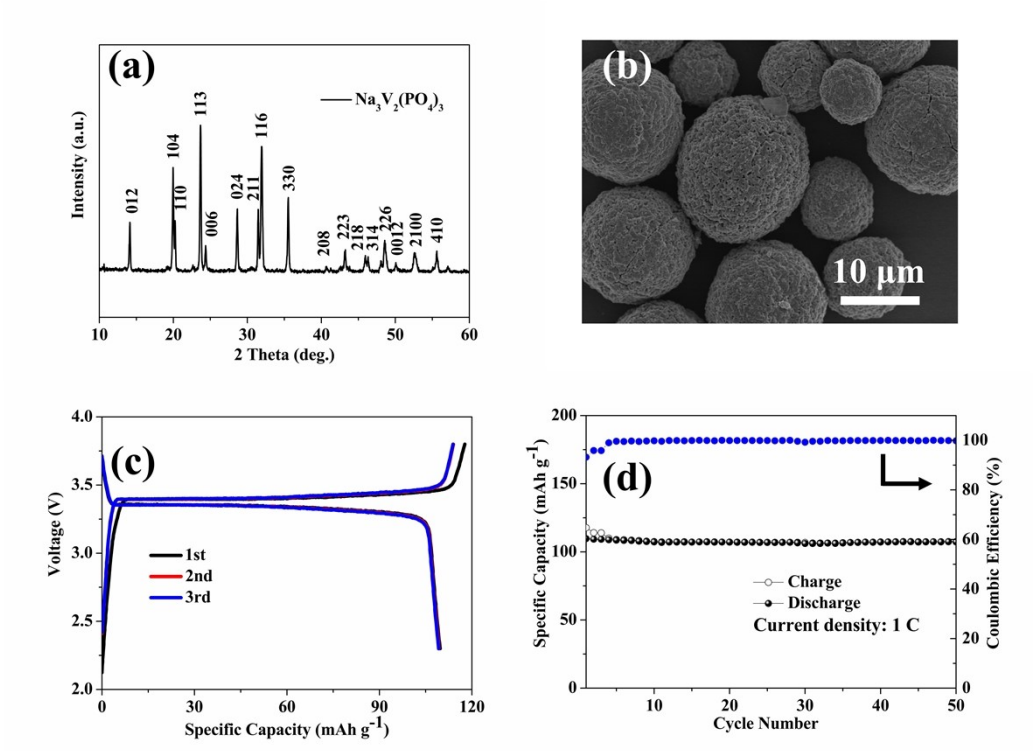

Fig. S7. Structural characterizations and electrochemical tests of $Na_3V_2(PO_4)_3$ (NVP) cathode. (a) XRD and (b) SEM image of NVP. (c) GCD curves of the first three cycles at 1C. (d) Cycling performance and corresponding CE at 1C.

Table S1. The performance comparison of SnO_2-$MoSe_2$ electrode with some reported electrode materials as full cell anodes.

Electrode	Cycle stability	Ref. No.
SnO_2-$MoSe_2$	106.8 mAh/g after 500 cycles at 0.5 A/g	This work
$Co_{2.4}Sn_{0.6}O_4$	73 mAh/g after 20 cycles at 0.05 C	1
FeCo-Se@NC	252.3 mAh/g after 50 cycles at 0.5 A/g	2
Fe_7Se_8-NCF	109 mAh/g after 200 cycles at 1 A/g	3
ZnS@NC@MoS_2	79.9 mAh/g after 200 cycles at 0.5 A/g	4
NC/$MoSe_2$@NC	104.8 mAh/g after 100 cycles at 0.1 A/g	5

References

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