Electronic Supplementary Material (ESI) for Nanoscale.
This journal is © The Royal Society of Chemistry 2019

Supporting Information

MoP hollow nanospheres encapsulated in 3D reduced graphene oxide networks as high performance anodes for sodium-ion batteries

Yanyou Yin,[a] Lishuang Fan,*[a] Yu Zhang,[a] Nannan Liu,[a] Naiqing Zhang,*[a,b] and Kening Sun*[a,b]

[a] State Key Laboratory of Urban Water Resource and Environment, School of Chemistry and Chemical Engineering, Harbin Institute of Technology, Harbin, 150090 (China)

[b] Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of Technology, Harbin, 150001 (China)

*Corresponding Author

Naiqing Zhang (znqmww@163.com)

Academy of Fundamental and Interdisciplinary Sciences, Harbin Institute of

Technology, Harbin, China

Tel: +451 86412153 Fax: +86-451-86412153

SUPPORTING INFORMATION CONTENT

Experimental Section

Preparation of H-MoO_2@GO: Graphene oxide (GO) was prepared by modified Hummers method. The H-MoO_2@GO was fabricated by a one spot hydrothermal method. 60 mg GO was added in 50 mL deionized water and ultrasonically dispersed for 30 min. After that, $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ (0.27 g), hydrochloric acid (3 M, 10 mL), PVP (0.13 g, K30) and vitamin C (0.13 g) were added into the above solution. After magnetic stirred for 30 min, the solution was transferred to a 100 mL Teflon-lined autoclave and heated at 180 ℃ for 48 h. After cooling to room temperature, the aerogel was washed by deionized water for several times and then freeze dried for 24 h to obtain H-MoO_2@GO.

Preparation of H-MoP@rGO: In a typical synthesis of H-MoP@rGO, 100 mg obtained H-MoO_2@GO and 500 mg $(NH_4)_2HPO_4$ were mixed with the help of a mortar. Then the mixture was heated to 850 ℃ at a rate of 3 ℃ min^{-1} and maintained for 2 hours under Ar/H_2 (5 wt%) atmosphere to produce H-MoP@rGO.

Morphology and structural characterization: The morphology of product was characterized by Field-emission scanning electron microscope (Hitachi Limited SU-8010) and transmission electron microscopy (Tecnai G2F30, FEI, US). XRD pattern was determined by PANalytical X'Pert PRO (PANalytical X'Pert PRO, monochromated Cu Kα radiation 40 mA, 40 kV) to characterize the crystal structure. Pore volume, specific surface area and N_2 adsorption/desorption isotherms were measured by an ASAP 2020 (Micromeritics). X-ray photoelectron spectroscopy (XPS) was performed with a Thermo Fisher Scientific K-Alpha (Fisher Scientific Ltd, Nepean, ON). Thermogravimetric analysis (TGA) was performed in air atmosphere at the rate of 10 ℃ min^{-1} to analyze the carbon content in the compound.

Electrochemical measurements: The anode slurry was prepared by mixing 70 wt% active materials, 20 wt% Super-P and 10 wt% carboxymethyl cellulose by high-speed electric agitator for 12h. The slurry was pressed onto a cleaned copper foil by a doctor-balding method and dried in a vacuum oven at 80 °C for 12h. The thickness of the prepared electrode film is 50 μm and the loading of active material is 0.1-0.3 mg cm^{-2}. The performance of the SIBs was tested using standard 2032 type coin cells in an argon-filled glove box. The separator was Glass fiber (GF/D) from Whatman and sodium foils were used as counter and reference electrodes. The electrolyte was 1.0 M NaClO4 in DIGLYME. The cells were galvanostatically charged and discharged over a cutoff voltage window of 0.01–3.00 V at room temperature on a battery test system (Shenzhen Neware Electronic Co., China). Cyclic voltammetry behavior was studied by CHI 650d electrochemical workstation at a scan rate of 0.1 mV s^{-1}.

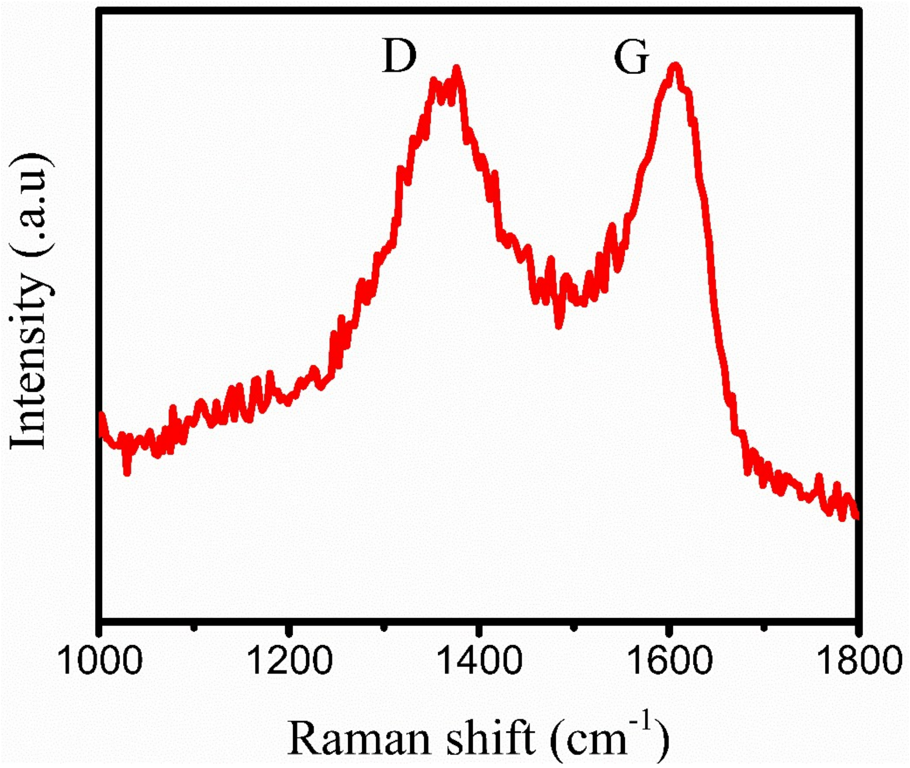

Figure S1. Raman spectrum of H-MoP@rGO.

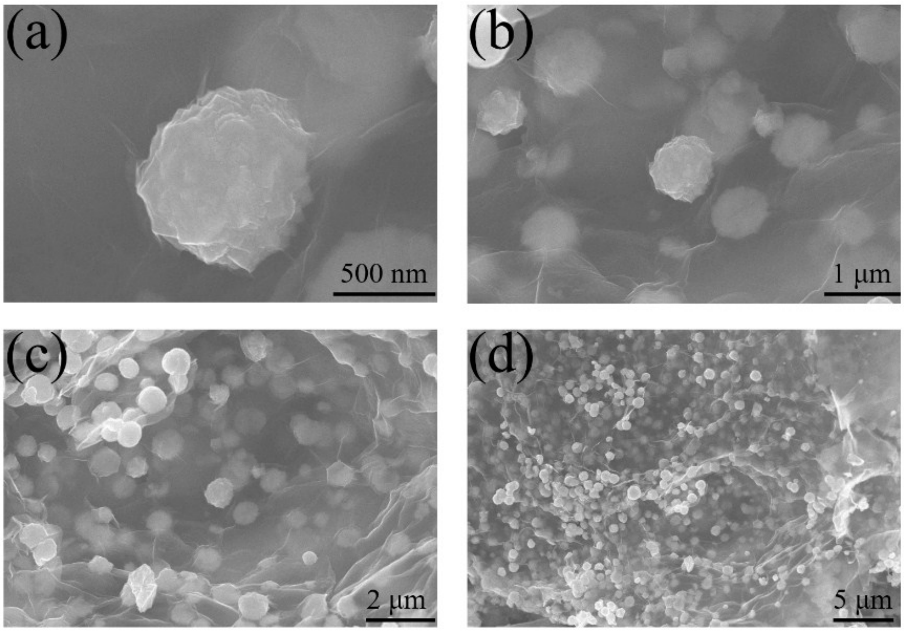

Figure S2. SEM images of MoO_2@GO.

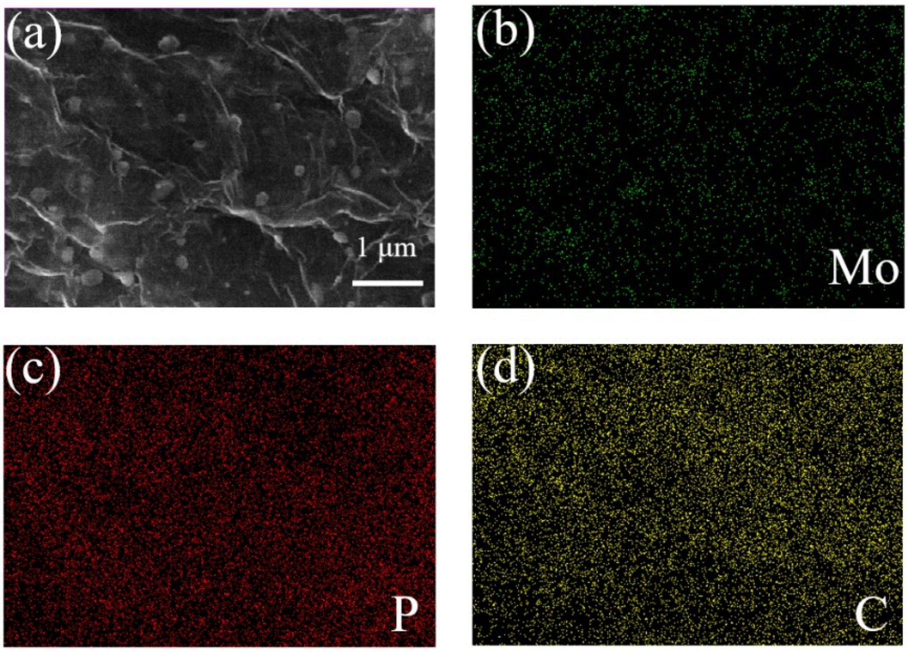

Figure S3. EDX mappings of Mo, P and C in the selected area of H-MoP@rGO.

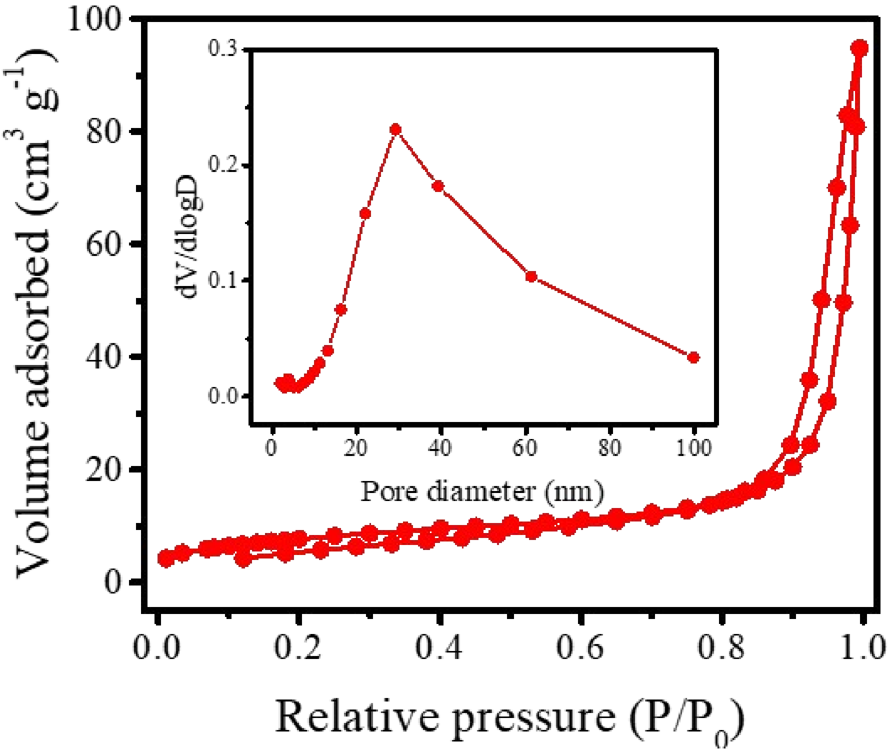

Figure S4. N_2 adsorption–desorption isotherm of H-MoP@rGO.

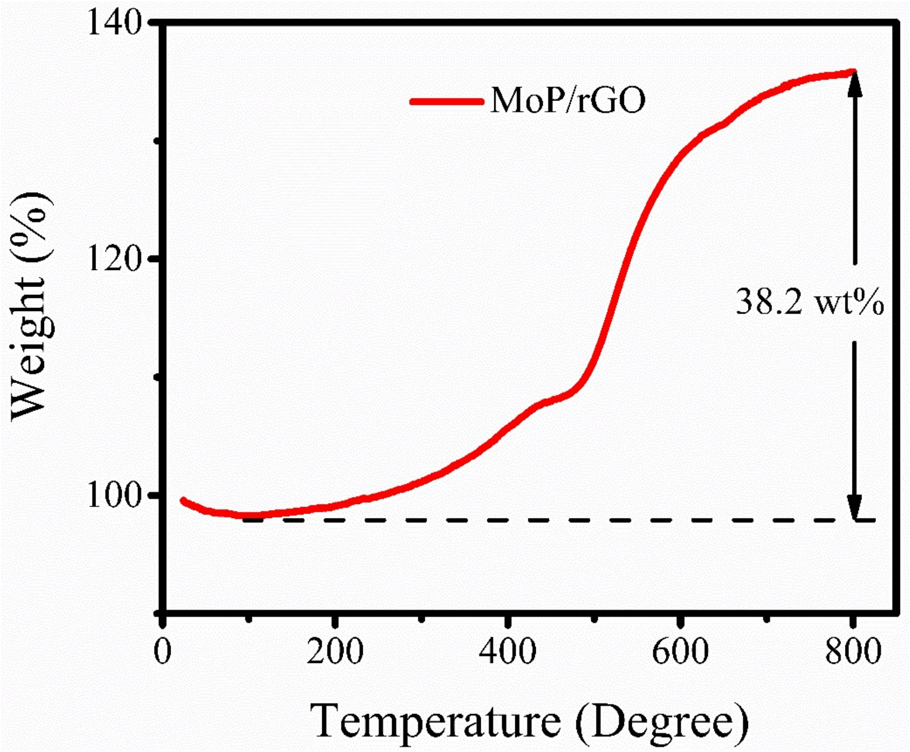

Figure S5. TG curves of H-MoP@rGO.

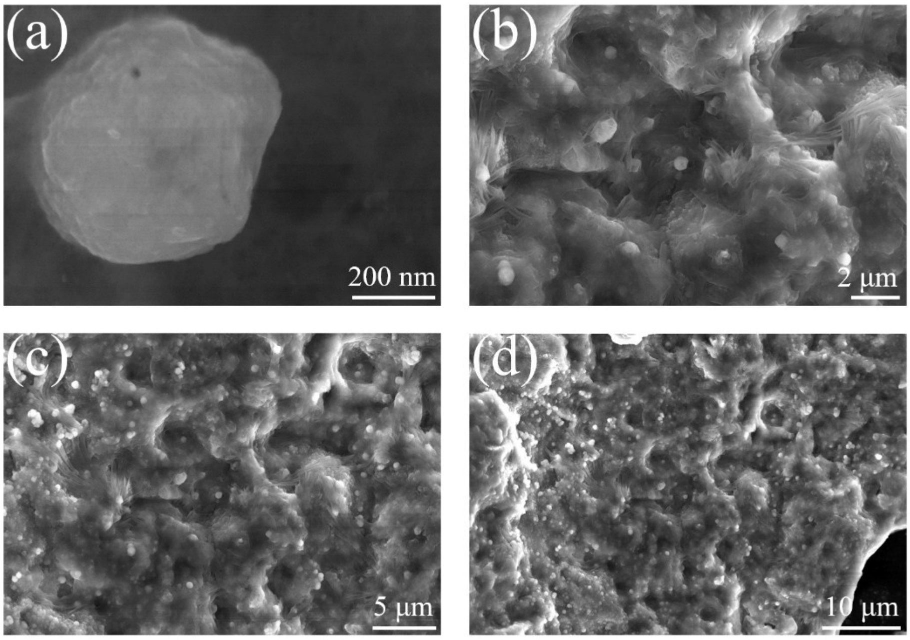

Figure S6. SEM images of H-MoP@rGO after 600 cycles at the current density of 1 A g^{-1}.

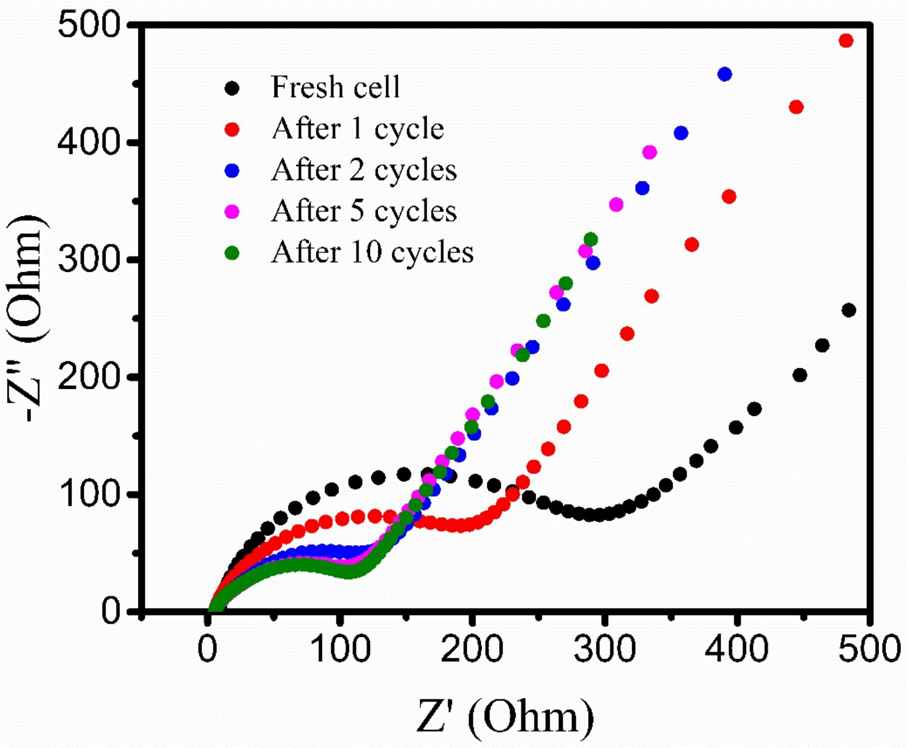

Figure S7. EIS curves of H-MoP@rGO at different cycles during the first 10 cycles.

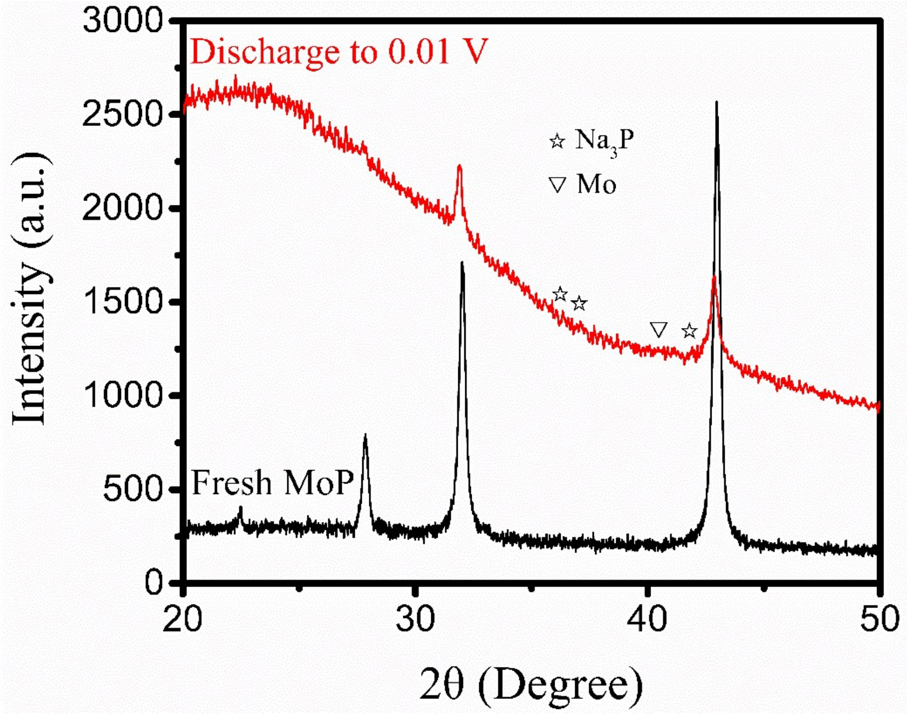

Figure S8. Ex-situ XRD patterns of H-MoP@rGO before discharge and discharge to 0.01 V.

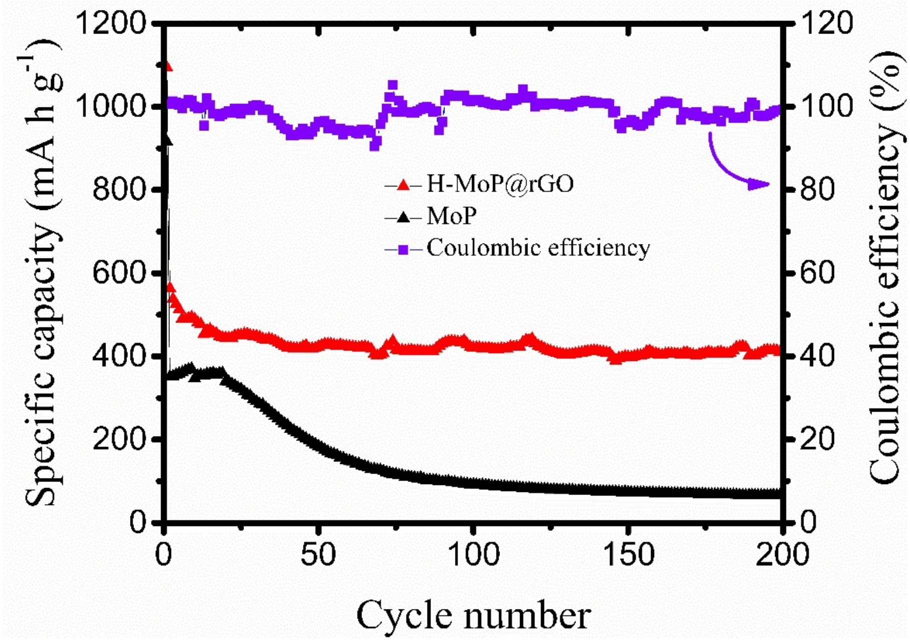

Figure S9. Cycle performance of H-MoP@rGO and MoP at a current density of 1 A g^{-1}.

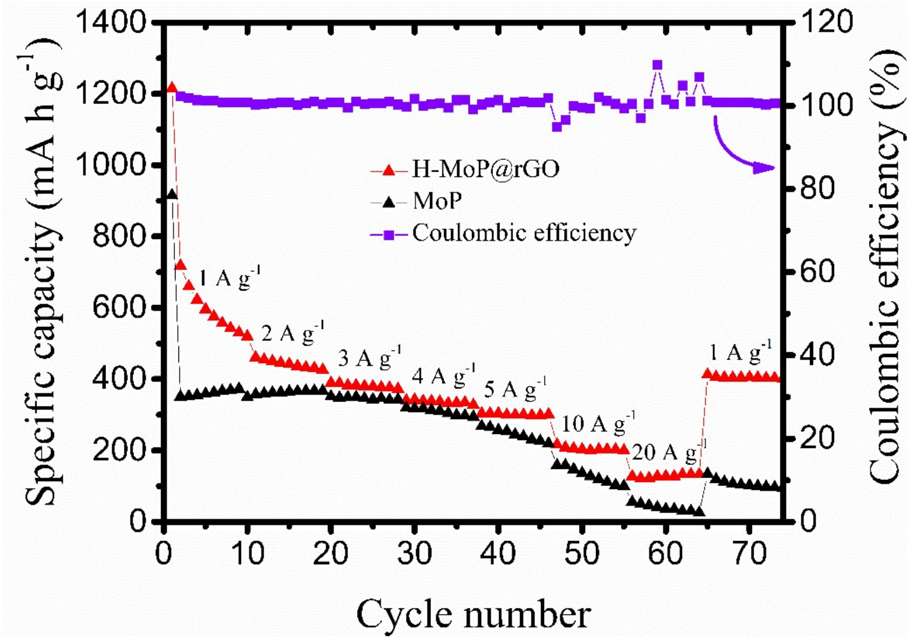

Figure S10. Rate performance of H-MoP@rGO and MoP.

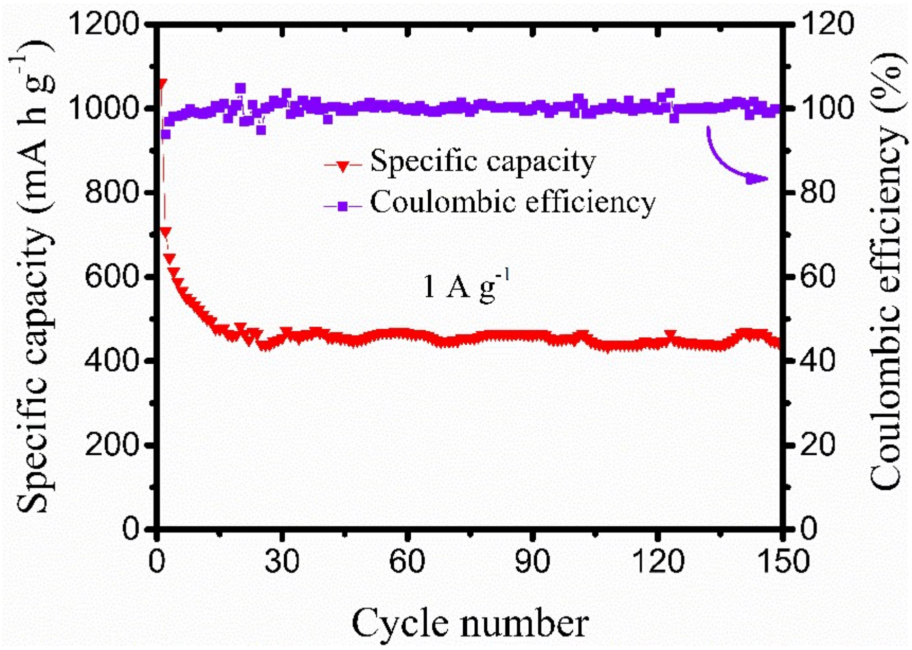

Figure S11. Cycle performance of H-MoP@rGO at a current density of 1 A g^{-1} with the load 0.8-1.2 mg cm^{-2}.