Supporting Information

A multi-interface bimetallic sulfoselenide-selenite heterojunction as battery-type cathode for high-performance supercapacitor

Xintong Lu, Qihang Chen, Lei Wu, Shuangxing Cui, Guochang Li, Wenna Zhao, and Lei Han

a School of Materials Science & Chemical Engineering, Ningbo University, Ningbo, Zhejiang 315211, China
b School of Biological and Chemical Engineering, NingboTech University, Ningbo, Zhejiang 315100, China.

* Corresponding Author.
E-mail: wnzhaonit.zju.edu.cn (W.N. Zhao), hanlei@nbu.edu.cn (L. Han)

Materials. All chemicals and reagents were used in the experiments without further treatment. Ethanol (C₂H₅OH), nickel nitrate hexahydrate (Ni(NO₃)₂·6H₂O), Sulfur powder, methanol (MeOH), cetyltrimethylammonium bromide (CTAB), sodium hydroxide (NaOH), potassium hydroxide (KOH), polyvinylidene chloride (PVDF) were purchased from Sinopharm, Selenium powder were purchased from Shanghai Meixing Chemical Co, cobalt nitrate hexahydrate (Co(NO₃)₂·6H₂O), activated carbon (AC) and 1-methyl-2-pyrrolidone were purchased from Aladdin Chemical Co.

Material characterization. The crystal structures of the materials were obtained by X-ray diffraction spectroscopy (XRD, Bruker D8 Advance) under Cu Kα (λ = 0.154178 nm) radiation. The morphological structures of the material were determined by field emission scanning electron microscopy (FESEM, Hitachi, S-4800, 20 kV), transmission electron microscopy (TEM, 200 kV) and high resolution transmission electron microscopy (HRTEM) combined with X-ray energy
dispersive spectroscopy (EDS) and elemental mapping. N$_2$ adsorption-desorption isotherms of the materials were obtained on a Mike 2020 HD88 instrument to evaluate the specific surface area and average porosity of the materials. The valence states of the different elements in the material determined by X-ray photoelectron spectroscopy (XPS) with Al K$_\alpha$ radiation (1486.6 eV) performed on a Thermo Scientific esca-lab-200i-xl spectrometer. Electrochemical tests were performed by an electrochemical analyzer system CHI660E (Chenhua, Shanghai, China) in 3 M KOH aqueous solution.

Fig. S1. XRD patterns of (a) NiCo-LDH, (b) Co$_3$S$_4$/Ni$_3$S$_2$ and (c) (Ni,Co)Se$_2$/(Ni,Co)SeO$_3$. 
**Fig. S2.** XPS spectra of (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1: (a) survey spectrum and (b) C 1s.

**Fig. S3.** (a) N$_2$ adsorption-desorption isotherms and (b) pore-size distribution curves of (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1.
Fig. S4. SEM images of (a) (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-2 and (b) (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-3.

Fig. S5. EDS spectrum of (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1 scraped from Ni foam.
Fig. S6. CV curves of (a) Co$_3$S$_4$/Ni$_3$S$_2$, (c) (Ni,Co)Se$_2$/(Ni,Co)SeO$_3$ and (e) NiCo-LDH; GCD curves of (b) Co$_3$S$_4$/Ni$_3$S$_2$, (d) (Ni,Co)Se$_2$/(Ni,Co)SeO$_3$ and (f) NiCo-LDH.
Fig. S7. Cycling performance of (a) (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1 and (b) (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1 // AC HSC device.

Fig. S8. SEM image of (Ni,Co)(Se,S)$_2$/(Ni,Co)SeO$_3$-1 after cycling test.
Fig. S9. CV curves of (a) (Ni,Co)(Se,S)_{2}/(Ni,Co)SeO_{3}-2 and (c) (Ni,Co)(Se,S)_{2}/(Ni,Co)SeO_{3}-3; GCD curves of (b) (Ni,Co)(Se,S)_{2}/(Ni,Co)SeO_{3}-2 and (d) (Ni,Co)(Se,S)_{2}/(Ni,Co)SeO_{3}-3; (e) EIS spectra; (f) areal capacitances.
Fig. S10. (a) Schematic illustration of ASCs; (b) CV curves of AC and (Ni,Co)(Se,S)_2/(Ni,Co)SeO_2-1 at a scan rate of 50 mV s\(^{-1}\); (c) CV curves of AC at different scan rates; (d) GCD curves of AC at different current densities.