Supporting Information

Template-free synthesized Ni nanofoams as nanostructured current collectors for high-performance electrodes in lithium ion batteries

Yujun Fu, Zhibo Yang, Xiuwan Li, Xinghui Wang, Dequan Liu, Duokai Hu, Li Qiao, Deyan He^{*}

School of Physical Science and Technology, and Key Laboratory for Magnetism and

Magnetic Materials of MOE, Lanzhou University, Lanzhou, 730000, China.

Supporting figures



Figure S1. SEM images of (a) the commercial Ni foam, and (b) the as-prepared Ni

nanofoam with 1 M nickel nitrate in the precursor solution.

^{*} Corresponding author. Tel.: +86 931 8912546; fax: +86 931 8913554.

E-mail address: hedy@lzu.edu.cn



Figure S2. SEM images of the Ni nanofoams synthesized with (a) 0.20 M, (b) 0.35 M, (c) 0.5 M and (d) 1.5 M nickel nitrate in the precursor solutions. The inserts are the corresponding high-magnification images.



Figure S3. SEM images of the Ni Nanofoam discs formed by pressing at (a) 2 MPa, (b) 10 MPa, and (c) 20 MPa. It is obvious that the morphology of the Ni nanofoams is almost independent of the pressure from 2 to 20 MPa.



Figure S4. TGA curves of the Ni nanofoam measured in the temperature range of 50 to 700 °C with a heating rate of 10 °C min⁻¹ in air. The sample was synthesized with 1 M nickel nitrate in the precursor solution. It can be seen that the mass of the as-prepared Ni nanofoam is independent of the temperature ranging from 50 to 280 °C, while it increases with raising the temperature from 280 to 600 °C due to the oxidation of the Ni nanofoam. The mass of the sample tends to be stable when the tested temperature is over 600 °C, indicating that the metallic Ni has been completely oxidized into NiO.



Figure S5. XRD patterns of the Ni/NiO nanofoams by oxidizing Ni nanofoams at 350 °C in air for 5 and 20 min, respectively. The sample was synthesized with 1 M nickel nitrate in the precursor solution. Besides the diffraction peaks from the Ni nanofoams (marked with "#"), the other peaks located at 37.26°, 43.29°, and 62.89° can be indexed to (111), (200), and (220) planes of cubic NiO, respectively (JCPDS Card No. 78-0643), suggesting that the Ni/NiO nanofoams are formed after oxidation. The diffraction peaks from NiO for the 20 min oxidation sample are stronger than those for the 5 min oxidation sample, indicating that the NiO shell becomes thicker with prolonging the oxidation time.



Figure S6. Raman spectra of the Ni nanofoams before and after oxidation. The sample was synthesized with 1 M nickel nitrate in the precursor solution. No Raman peaks were observed before oxidation since metallic Ni has no active Raman vibration mode. After oxidation at 350 °C for 5 min, a broad band centered at 512 cm⁻¹ can be assigned to the vibration modes of Ni-O bond, which indicates the NiO existence in the material.^{1, 2} While after oxidation for 20 min, the band of 512 cm⁻¹ becomes stronger and the other bands of Ni-O bond centered at 732, 901 and 1080 cm⁻¹ can be observed, indicating that the NiO shell becomes thicker with prolonging the oxidation time.



Figure S7. Cycling performance of the Ni/NiO nanofoam electrode tested at a current density of 0.5 C. The Ni nanofoam was synthesized with 1 M nickel nitrate in the precursor solution, and then oxidized at 350 °C in air for 20 min. It can be seen that, at the 20th cycle, the discharge capacity maximizes the value of about 799 mAh g^{-1} . However, a relative low discharge capacity of 580 mAh g^{-1} was attained after 200 cycles, retaining 72% of the maximum capacity. Thus, the capacity retention of the present thick NiO electrode is poorer than that of the thin NiO electrode shown in Fig. 4c.



Figure S8 Nyquist plots of the Ni/NiO electrodes obtained by oxidizing the Ni nanoforms for 5, 20 and 80 min in air, respectively. To understand the metallic Ni nanofoam can enhance the electronic conducting capability of the entire electrode, electrochemical impedance spectra (EIS) were carried out to analyze and compare the charge-transfer resistance of the different electrodes. All the electrodes experienced 10 cycles at a 0.2 C rate before being charged to 3.0 V with a subsequent relaxation period of 5 h. Corresponding Nyquist plots are presented in Figure S8, the charge transfer resistance (R_{ct}) increase with the oxidizing time increasing.

Reference

- [1] Li, X.; Dhanabalan, A.; Bechtold, K.; Wang C. *Electrochem. Commun.* 2010, *12*, 1222.
- [2] Dietz, R.E.; Parisot, G.I.; Meixner, A.E. Phys. Rev. B 1971, 4, 2302.