Supplementary Information for:

Novel concept of rechargeable battery using iron oxide nanorods anode and nickel hydroxide cathode in aqueous electrolyte

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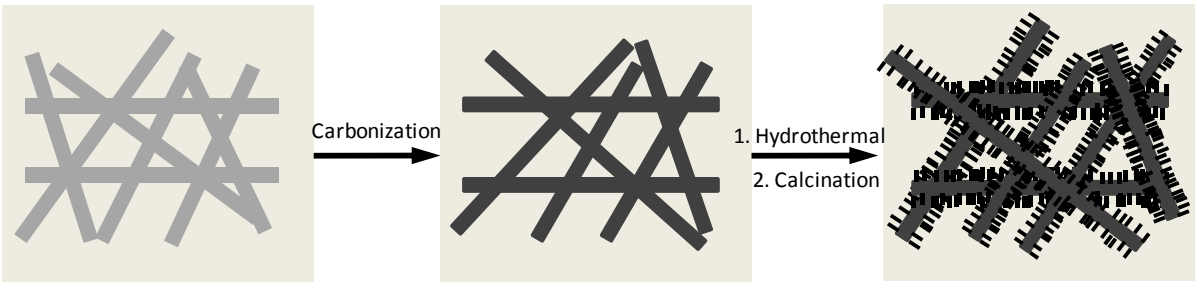
SI-1. Synthesis of carbon nanofibers (CNFs)

CNFs were synthesized by electrospinning.[1] In a typical experiment, 0.50 g polyacrylonitrile (PAN) was dissolved in 7.30 g N,N-dimethylformamide (DMF) at 60 °C and then cooled down to room temperature naturally under continuous stirring. The solution was electrospun using a conventional electrospinning setup (MECC NANON-01A, Japan) and a 27 G × 1/2″ needle with inner diameter of 200 μm under working voltage of 11.5–12.5 kV. The needle tip-to-plate substrate distance was 15 cm. The flow rate was 0.4 ml h^{-1}. The nanofibers were collected on aluminium foil and dried in a vacuum oven at 60 °C for 72 h. The dried nanofibrous mat was then heated in a Carbolite tube furnace to convert PAN to carbon. The temperature was ramped from 25 °C to 280 °C at 1 °Cmin^{-1} and kept at 280 °C for 1 h in atmospheric environment (stabilization). It was then ramped to 550 °C at 10 °Cmin^{-1} and kept at 550 °C for 2.5 h in an argon environment (carbonization) before cooling down to room temperature. The carbonized mat is tough enough for handling such as being cut into different shapes.

SI-2. Preparation of α-Fe_2O_3/CNFs composite

The Fe_2O_3/CNFs composite was prepared by a seed, catalyst, and surfactant-free hydrothermal method, the recipe of which was slightly modified from previous reports on preparation of α–Fe_2O_3 nanorod arrays.[2,3] In a typical experiment, a piece of carbon nanofibrous mat (1 cm × 2 cm) was placed within a 50 ml sealed Teflon autoclave containing a solution (30 ml) consisting of 0.8 g $FeCl_3 \cdot 6H_2O$ and 2.1 g $NaNO_3$. $NaNO_3$ was employed as a structure-directing agent to facilitate the relatively uniform growth of 1D nanorods. The hydrothermal reaction was conducted at 100 °C for 12 h. After cooling down to room temperature, the mat was rinsed several times with distilled water and then dried at 60 °C. The Fe_2O_3 has a strong adhesion to the carbon substrate even after ultrasonication for 10 min. Finally, annealing in Ar gas at 450 °C for 1 h was carried out for the phase transition from the resulting precursors (FeOOH) to pure α–Fe_2O_3. The amount of deposited iron oxide (about 5 mg/cm^2) was measured by a microbalance with an accuracy of 0.1 mg.



Scheme S1. Synthesis process of the Fe_2O_3/CNFs

SI-3. Characterization

The morphologies of the Fe_2O_3/Carbon nanofibers composites were observed under field-emission scanning electron microscope (FESEM) and TEM. The X-ray diffraction (XRD) patterns in Bragg's angle (2θ) ranging from 10 to 70° at room temperature were collected on a Bruker GADDS diffractometer with Cu Kα radiation of wavelength λ = 0.15418 nm. Thermogravimetric analysis (TGA) was carried out on an SDT600 apparatus with a heating rate of 10 °C min^{-1} in N_2.

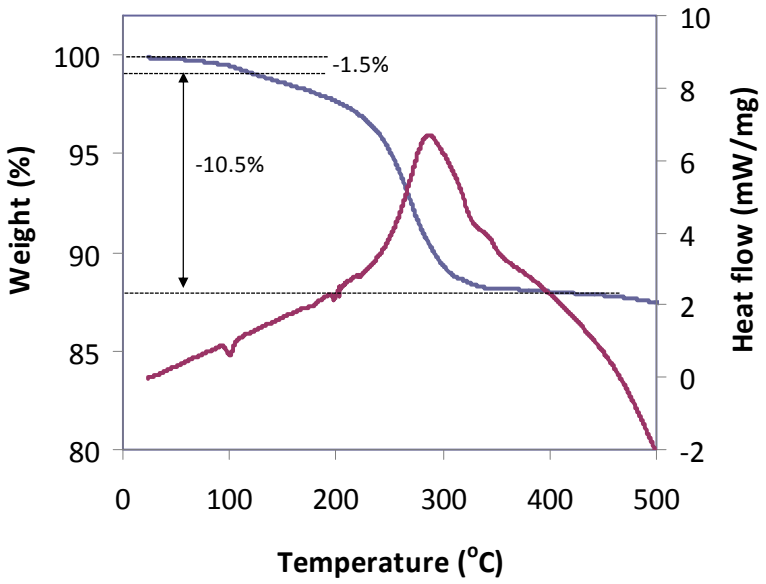


Figure S1. TGA and DTA curves of the FeOOH/CNFs.

SI-4. Electrode preparation and electrochemical measurements

The Fe_2O_3/CNFs composite (1 cm × 2 cm) were used directly as the anode. Co-coated β-$Ni(OH)_2$ powder was provided by Tanaka Chemical Corporation. The cathode was prepared by incorporating the paste consisted of 88 wt% Co-coated β-$Ni(OH)_2$, 5 wt% cobalt oxide powders, 5 wt% carbon black, and 2 wt% polyvinyl alcohol (Average Mw *ca*. 50,000) into nickel foam,

drying in 80 °C and pressing into disk under 20 MPa. For the charge/discharge and cyclic voltammetric tests of both Fe_2O_3 and $Ni(OH)_2$ in the aqueous electrolyte of 1 M LiOH and 3 M KOH, each electrode was characterized using a three-electrode cell, in which the Pt and Hg/HgO electrode were used as counter and reference electrodes, respectively. The capacity was determined based on the weight of the active materials. A two-electrode glass cell was constructed with $Ni(OH)_2$ as the cathode and Fe_2O_3/CNFs composite as the anode. The cells were charged and discharged at 25 °C on a Maccor 4200 battery test system.

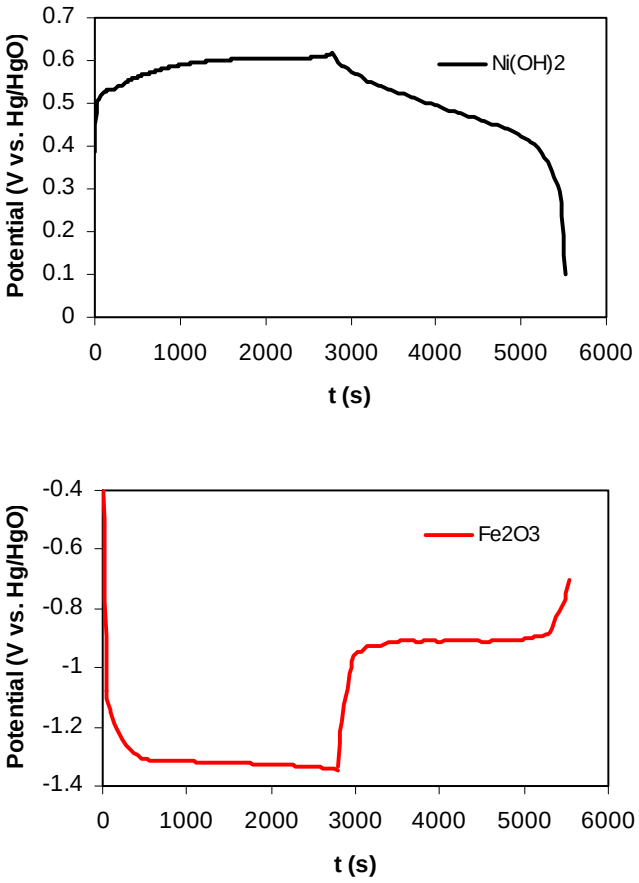


Figure S2. Charge/discharge curves of the $Ni(OH)_2$ and Fe_2O_3/CNFs electrodes *vs.* Hg.HgO reference electrode at a current rate of 100 mA g^{-1} for 5th cycle.

References

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3 W. Zhou, C. Cheng, J. Liu, Y. Y. Tay, J. Jiang, X. Jia, J. Zhang, H. Gong, H. H. Hng, T. Yu, H. J. Fan, *Adv. Funct. Mater.*, 2011, **21**, 2439.