Electronic Supplementary Information

Electrochemical Performances of LiFePO4-based Heat-treated activated carbon Electrode

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Experimental

Heat-treatment of activated carbon

Activated carbon was prepared by the H_3PO_4-activation of wood-based raw materials and was supplied by Power Carbon Technology Ltd. To vary the surface conditions and pore structure, the activated carbon was heat-treated at 500°C, 700°C, 1000°C, and 1300°C in an inert atmosphere for 1h. The non-heat-treated and heat-treated activated carbon at various temperatures were referred to as AC, AC-500, AC-700, AC-1000, and AC-1300.

Analyses of activated carbon

The shape and surface of the activated carbon were observed using field-emission scanning electron microscopy (FE-SEM) (Hitachi, S-4800). The nitrogen adsorption-desorption isotherm was evaluated at -196 °C using a BELSORP-Max (MacrotracBEL). The specific surface area was calculated using the Brunauer-Emmett-Teller (BET) method. The pore volume and average pore size were calculated using the Barrett-Joyner-Halenda (BJH) method. The functional groups present on the surface of the activated carbon were analyzed using high-performance X-ray photoelectron spectroscopy (XPS) (K-Alpha).

Fabrication of electrodes and half cells

Activated carbon and LiFePO$_4$ (P600A, Pulead) were used together as the active materials. Hereinafter, active materials are referred to as LFP. LiFePO$_4$ and activated carbon were mixed in a ratio of 95:5 (wt.%). LFP or the active materials were combined with carbon black (CB) and polyvinylidene fluoride (PVDF, Solvay) in a ratio of 85:10:5 (wt.%) to prepare slurries. These slurries were coated with Al foil and vacuum-dried at 120 °C for 12h. The dried electrodes were roll-pressed to achieve an electrode thickness of 60 μm. The electrodes cut in 2.5 × 2.5 cm^2 were used as working electrodes, and lithium foil was used as a counter electrode. A separator was placed between the electrodes to assemble the pouch cell. An electrolyte was prepared and used by dissolving 1 M LiPF$_6$ in a solvent containing ethylene carbonate (EC) and ethyl methyl carbonate (EMC) in a volumetric ratio of 3:7.

Evaluations of electrodes and half cells

The active material resistance (Ωcm) of the electrodes was calculated by measuring the multi-probe resistance (RM2610, HIOKI) and dividing it by the electrode thickness. The capacity, C-rate, and cycle characteristics of the electrodes were evaluated using the charge-discharge tester (Maccor, MC-4) over the voltage range of 2.5–4.2

V at 25°C. The capacities of the activated carbon and LFP were obtained in the voltage region of the voltage profiles, and the gravimetric capacitance (Fg^{-1}) of the activated carbon was calculated at the initial discharge slope using the following equation:

$$C = \frac{i\Delta t}{\Delta V}$$

where Δt represents the time period, ΔV represents the voltage change, and i represents the constant discharge current.

The C-rate characteristics were measured by charging at 0.2 C and discharging in the current range of 0.2–10 C, and the charge-discharge cycle characteristics were measured by repeating 0.2 C charges and 0.5 C discharges.

AC impedance analysis of the electrodes was performed using an impedance analyzer (Wonatech MP2) within a frequency range of 5 mHz–10 MHz and at an amplitude of 10 mV.
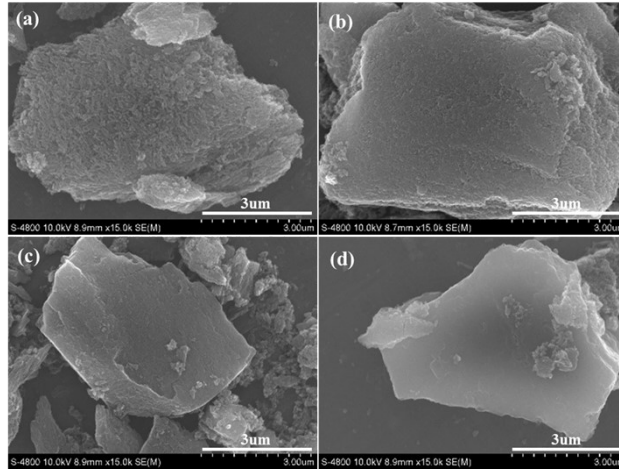
Fig. S1 SEM images of (a) AC, (b) AC-500, (c) AC-1000 and (d) AC-1300.

Fig. S1 Porosimetric features of AC-HTT as obtained from the analysis of nitrogen adsorption/desorption isotherms ; S_{BET} : surface area, V_{tot} : total pore volume, r_{avg} : mean pore diameter, V_{micro} : micropore volume, V_{meso} : mesopore volume, V_{micro}/V_{tot} : micropore volume percent.

Activated carbon	S_{BET} [m^2/g]	V_{tot} [cm^3/g]	r_{avg} [nm]	V_{micro} [cm^3/g]	V_{meso} [cm^3/g]	V_{micro}/V_{tot} [%]
AC	1466.5	1.232	3.36	0.396	0.835	32
AC-500	1460.1	1.257	3.44	0.408	0.849	32
AC-700	1338.5	1.122	3.35	0.378	0.743	34
AC-1000	1201.6	0.978	3.26	0.353	0.625	36
AC-1300	1149.9	0.971	3.38	0.331	0.640	34