

Supporting information

1. Material synthesis.

Typical synthesis procedure are as follows: 8 mmol maleic acid is added into a beaker with 40 mL deionized water and agitating for 10 minutes, following with 8 mmol copper (II) oxide powder is added in the former solution with sustained stirring for another hour. After that, the suspension is moved to a water bath device, heating at 70 °C with continuous stirring, gather the navy blue precipitate after 6 hours, wash the as prepared sample several times with deionized water and ethanol, drying overnight at oven and obtain the copper maleate hydrate (CMH) finally.

2. Characterization.

The crystal structure and morphology was characterized by powder X-ray powder diffraction (Bruker, D8 Advance A25 X) measurement equipped with a Cu K α radiation (1.54184 Å). Thermogravimetric Analysis (TGA, Q50 USA) is tested at a nitrogen atmosphere, with a 10 °C min⁻¹ heating rate from room temperature up to 700 °C. X-ray photoelectron spectroscopy (XPS, Escalab 250xi, Thermo Scientific) had been used to calculate the element's valence information. The specific surface area and pore size distribution were analyzed by Quadrasorb evo 2QDS-MP-30 (Quantachrome Instruments, USA). The microstructure and surface details was gathered by a Field emission scanning electron microscope (FESEM, JEOL, JSM-7800F). Electrochemical properties characterization of the sample was performed by a LAND battery test system (Wuhan, Kingnuo, China). A half-cell (CR2032) was assembled at the glove box (DELLIX, LS8000S) filled with Argon, both the content of oxygen and vapor should be less than 1 ppm.

3. Electrochemical measurements.

For the working electrode, a weight ratio of 50 % as-prepared sample, 40% acetylene black and 10% poly (vinylidene fluoride) were fully mixed and dispersed with 1-methyl-2-pyrrolidinone at a agate mortar, then the slurry was cast on a clean copper foil and dried at a 120 °C vacuum oven overnight, lithium metal apply as a counter and reference electrode. The electrolyte is 1 M LPF₆ dissolved in a mixture of ethylene carbonate, diethyl carbonate and dimethyl carbonate with a ratio of 1:1:1, and polypropylene film (celgard2400) a separator. Cyclic voltammetry (CV) test was completed by a CHI760E electrochemical measurement system (Shanghai, Chen hua) via a scan rate of 0.2 mV s⁻¹ at the voltage range from 0.01 V to 3 V. Electrochemical impedance spectroscopy (EIS) measurements were tested under a frequency range from 0.01 Hz to 10000 Hz through a Zahner electrochemical workstation (Zennium, IM6, Germany). Both the electrochemical test are completed at room temperature.

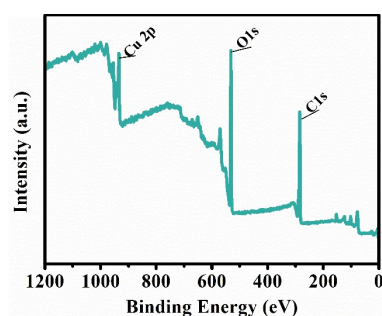


Fig. S1 XPS total spectrum of copper maleate hydrate

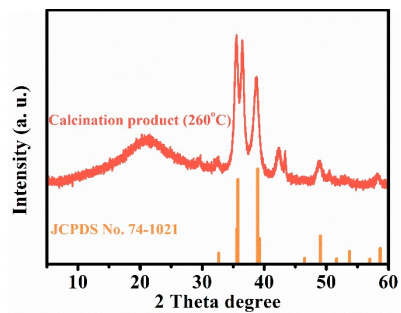


Fig. S2 PXRD result of the 12 hours calcination at argon atmosphere of CMH

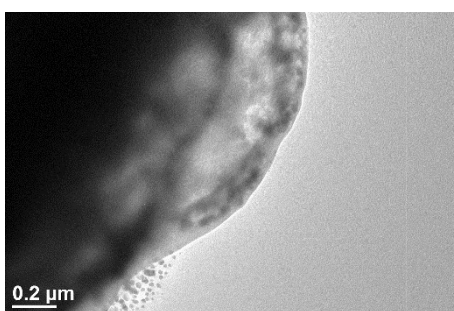


Fig. S3 Low magnification TEM image of copper maleate hydrate

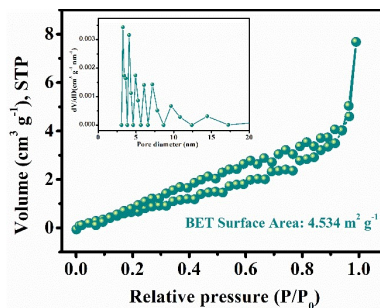


Fig. S4 BET test results of copper maleate hydrate

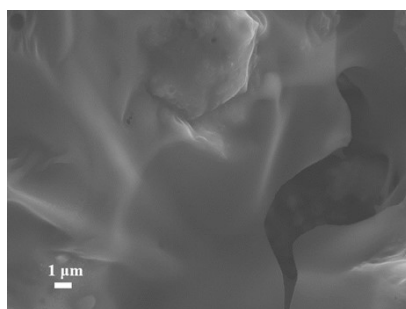


Fig. S5 FESEM images after 150 cycles at 0.2 A g⁻¹ of the electrode

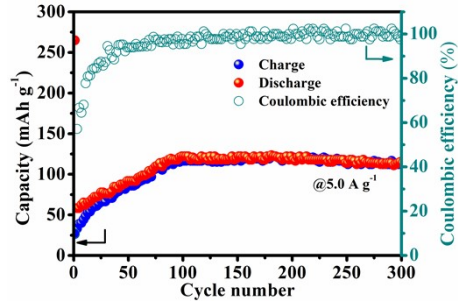


Fig. S6 Copper maleate hydrate cyclic performance at 5.0 A g⁻¹

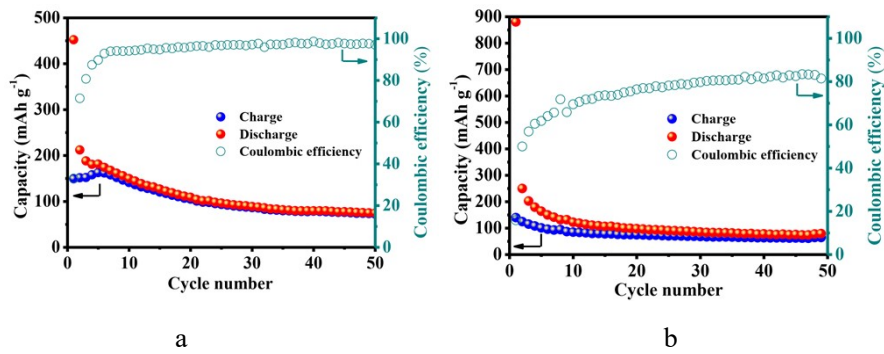


Fig. S7 cycle performance of CMH applied as anode material for (a) sodium and (b) potassium ion battery (current density: 0.2 A g⁻¹)

	R_u / ohm	R_{ct} / ohm	$D (Li^+) / cm^2 s^{-1}$
Fresh	1.96	70.38	5.058×10^{-14}
After 3 cycles	2.15	83.27	4.131×10^{-14}

Table. S1 Simulation results and calculation consequence of the diffusion coefficient of lithium ion.

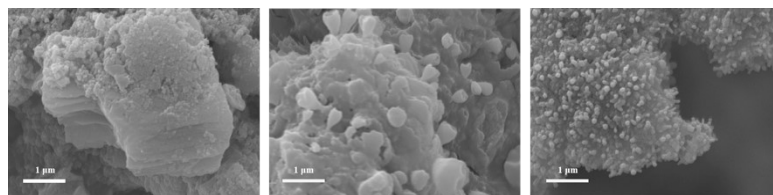


Fig. S8 FESEM images at the first cycle. (a) Before cycle; (b) Discharge to 0.01V and (c) Charge back to 3.0V.