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$NaCrO_2$@C Flexible Free-standing Cathode via Electrospinning Technique for Sodium-Ion Batteries

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Experimental Section

Synthesis of $NaCrO_2$@C flexible free-standing cathode. $NaCrO_2$(NCO) powders were prepared by a freeze-drying assisted sol-gel method consulting to Ref. 18. Firstly, 1 g polyacrylonitrile (PAN) and 1 g NCO were dissolved into 10 g dimethylformamide (DMF) with well stirring at 60 ℃ for homogeneous dispersion. After 12 h, the green NCO precursor solution for electrospinning was obtained.

The $NaCrO_2$@C(NCO@C) flexible free-standing cathode was synthesized by an electrospinning technique. NCO precursor solution was transferred into a 5 ml plastic syringe equipped with a 21- gauge blunt tip needle. The solution feeding rate was set to be 0.8 ml h^{-1} controlled by a syringe pump. The oil paper was used as a receiving base. The voltage between the oil paper and the needle was adjusted to 15 kV, and the distance of them was 15 cm. The collection speed was 400 rpm. The round-trip distance of needle was 50 mm with 30 mm s^{-1} movement speed. Then, the as-collected membrane was stabilized at 80 ℃ for 12 h under vacuum conditions to remove residual DMF and eliminate part of static electricity, and then heat-treated at 280 ℃ for 2 h in air with a ramping rate of 1 ℃ min^{-1}. Finally, the above membrane was carbonized at 600 ℃ for 8 h in a flowing Ar-H_2 atmosphere with a ramping rate of 2 ℃ min^{-1}. After being cooled, the NCO@C flexible free-standing cathode was

obtained and stored in an Ar-filled glove box. The synthesis process of NCO@C flexible free-standing cathode is illustrated in Fig. S1.

Physical Characterization. To confirm the crystal structure of NCO electrochemical active materials in NCO@C flexible free-standing cathode, a powder X-ray diffraction (XRD) was carried out on a Bruker D8 Advance with Cu K_α radiation. Scanning electron microscopy (SEM, SU8220) was employed to analyze the morphology. The elemental distribution of NCO@C flexible free-standing cathode was detected by an energy-dispersive spectrometry (EDS) attached to the SEM. Through X-ray photoelectron spectroscopy (XPS, Escalab 250Xi), the included elements and their valences in NCO@C flexible free-standing cathode were determined. Thermodynamic surface tensions were conducted on contact angles instrument (TEP-1000A). The carbon content of the sample was determined by a thermogravimetric analyzer (TGA) in the nature atmosphere.

Electrochemical Measurements. All electrochemical measurements were carried out with CR2032 coin half-cells assembled in an Ar-filled glove box. The synthesized NCO@C flexible free-standing membrane itself was used as the cathode, and sodium metal was served as a counter electrode. Glass fiber (CAT No. 1823-090, Whatman) was chosen as the separator. The electrolyte was 1.0 M $NaClO_4$ in ethyl carbonate (EC)/propylene carbonate (PC) (1:1, vol) with 5% fluoroethylene carbonate (FEC). Galvanostatic charge/discharge tests were performed in 2.3–3.6V with a battery test instrument (LAND, CT2001A, China) at room temperature. Cyclic voltammetry (CV) test was carried out on an electrochemical workstation (Chenhua, CHI660E, China) at 0.1 mV s^{-1} in a potential window of 2.3–3.6 V.

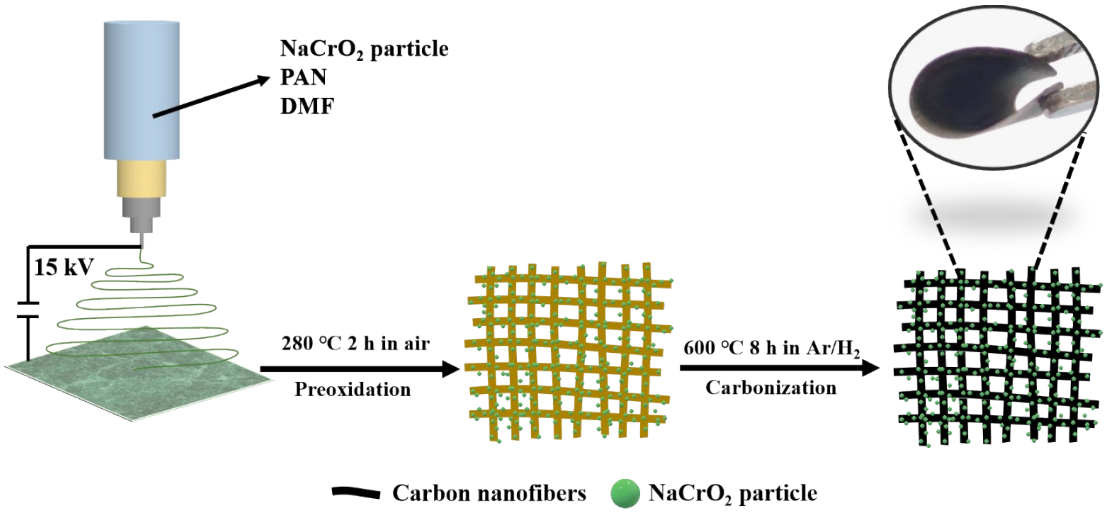

Fig. S1 Schematic diagram of the synthesis process of NCO@C flexible free-standing cathode.

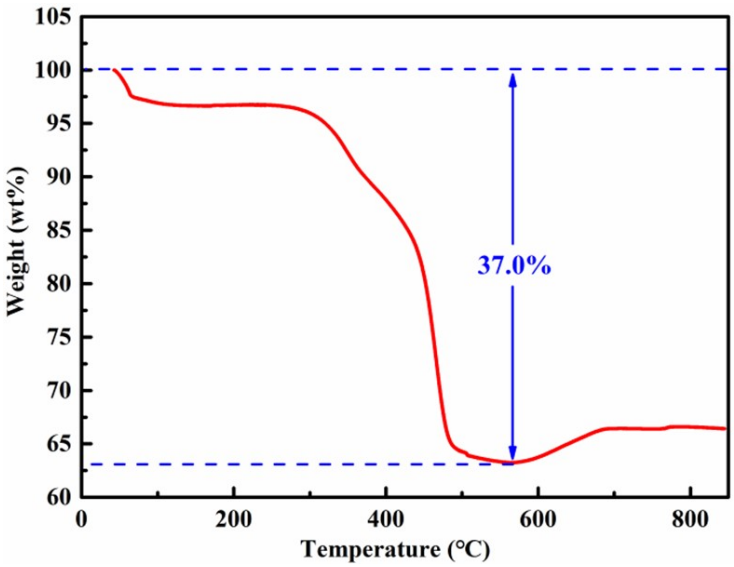

Fig. S2 TGA curve of NCO@C flexible free-standing cathode tested in air with a heating rate of 10 ℃ min^{-1}.

Fig. S3 Mechanical properties of the NCO@C flexible free-standing cathode.