Supplementary Information

Direct Regeneration of Hard Carbon Anodes from Spent Sodium-Ion Batteries via Flash Joule Heating

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Table of Contents

for

Supplementary Information

1. Supplementary figures

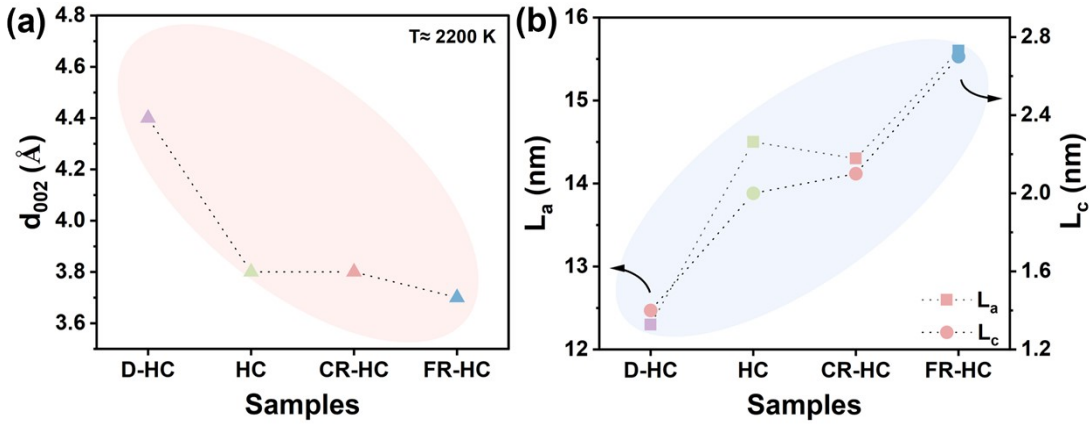

Fig. S1. a) Measured $d_{(002)}$ values of different HC samples. b) Average L_a and L_c of graphitic micro-domains in different HC samples.

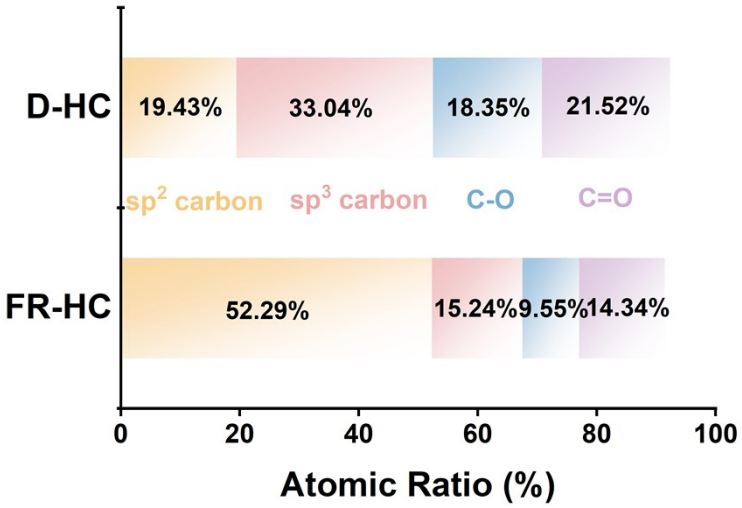

Fig. S2. The atomic ratio of different C chemical states of FR-HC and D-HC.

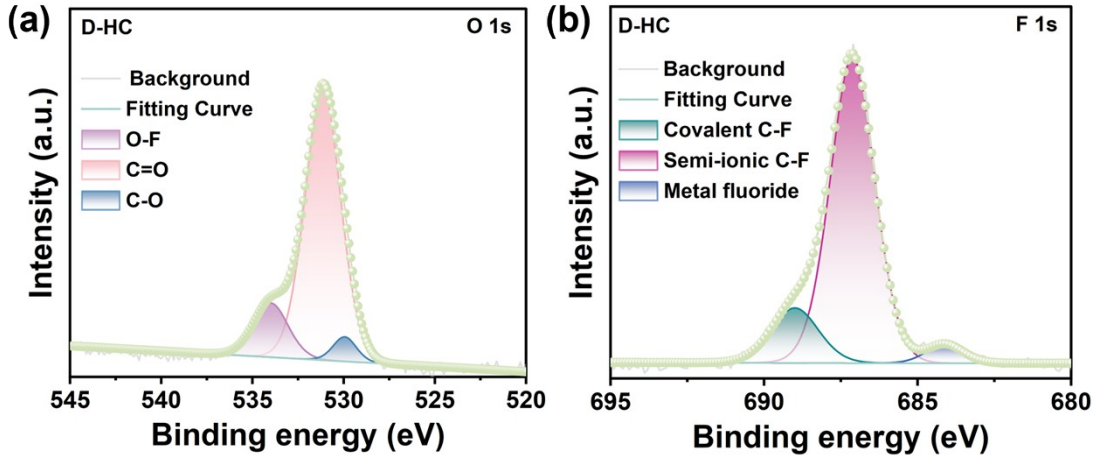

Fig. S3. The XPS spectra of a) O 1s and b) F 1s for D-HC electrode.

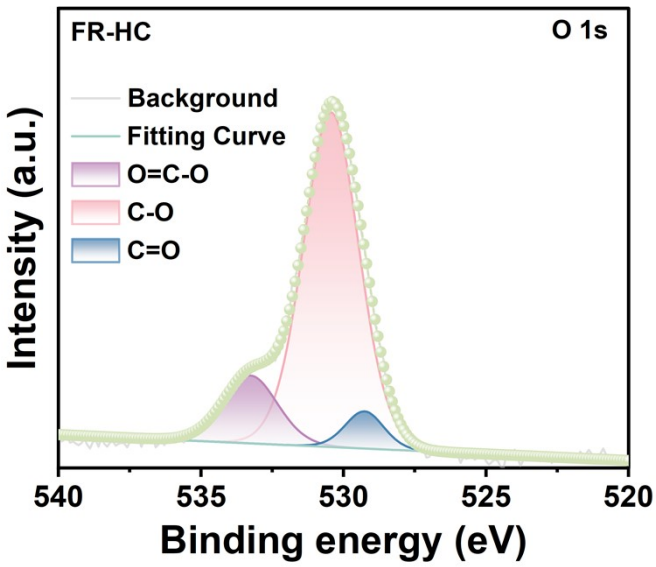

Fig. S4. The XPS spectra of O 1s for FR-HC electrode.

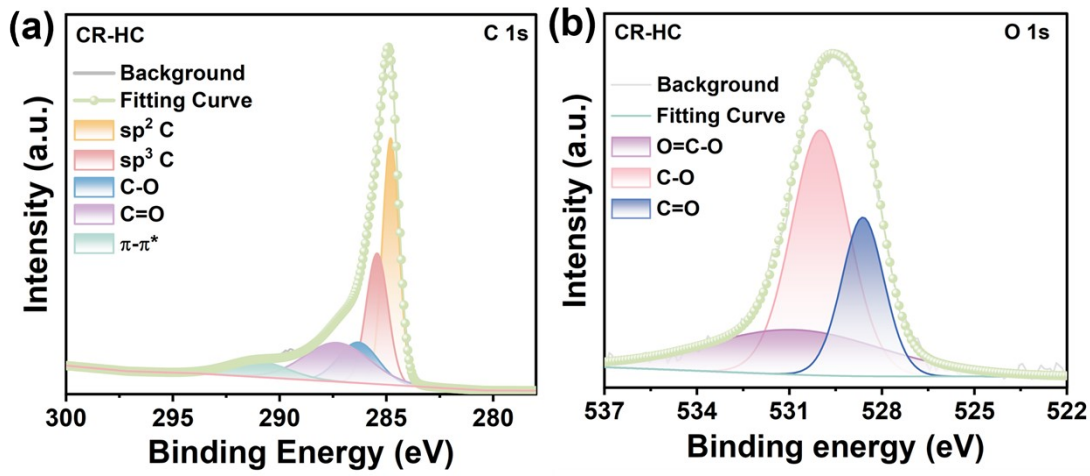

Fig. S5. The XPS spectra of a) C 1s and b) O 1s for CR-HC electrode.

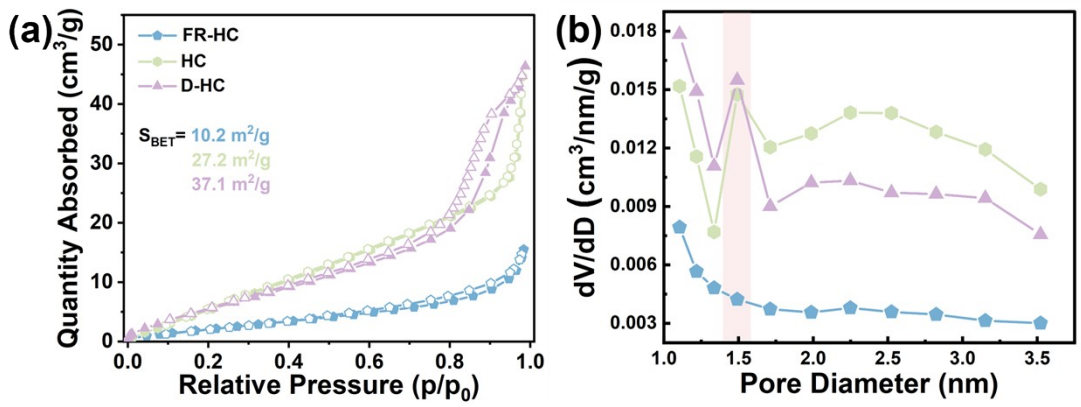

Fig. S6. a) N_2 adsorption/desorption curves and b) pore size distributions of FR-HC, HC and D-HC samples.

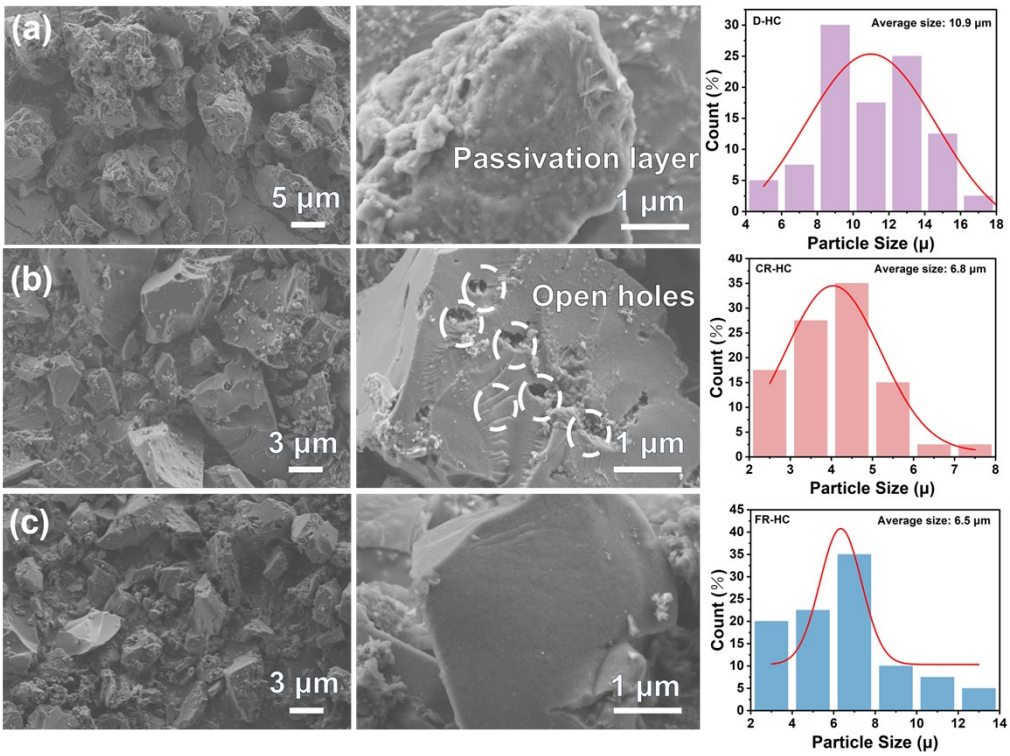

Fig. S7. SEM images of various HC materials. (a) D-HC. (b) CR-HC. (c) FR-HC. (d-f) statistical surveys showing the different HC sample sizes. The number of samples N = 40.

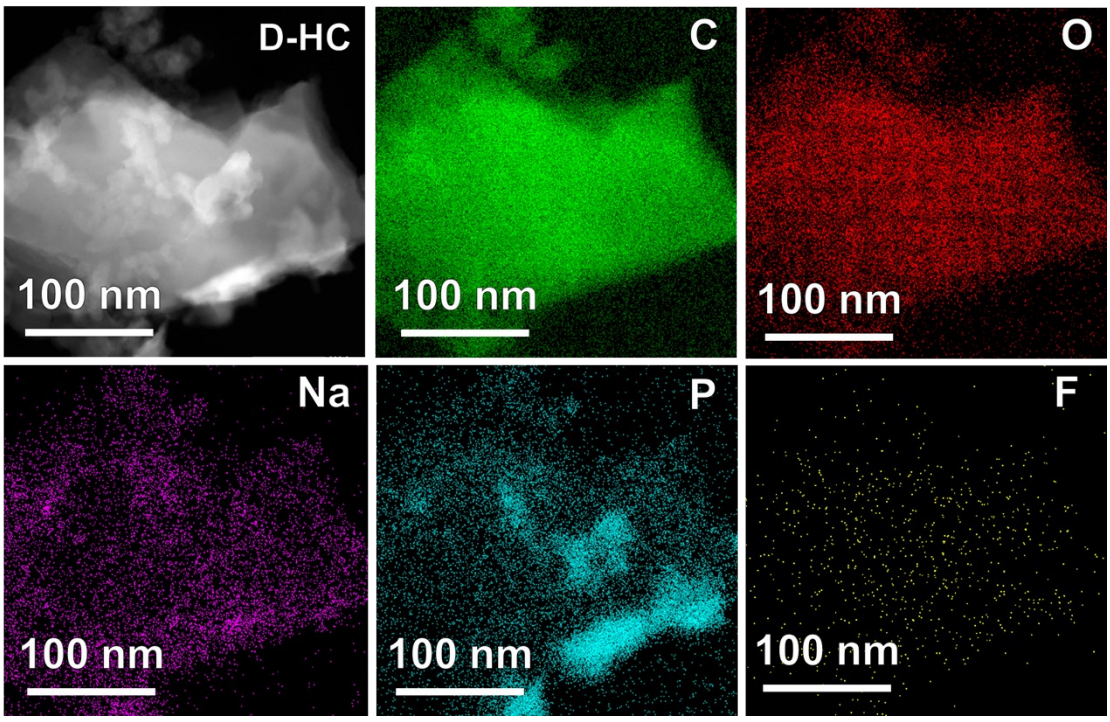

Fig. S8. Transmission electron microscope (TEM)-EDS of D-HC.

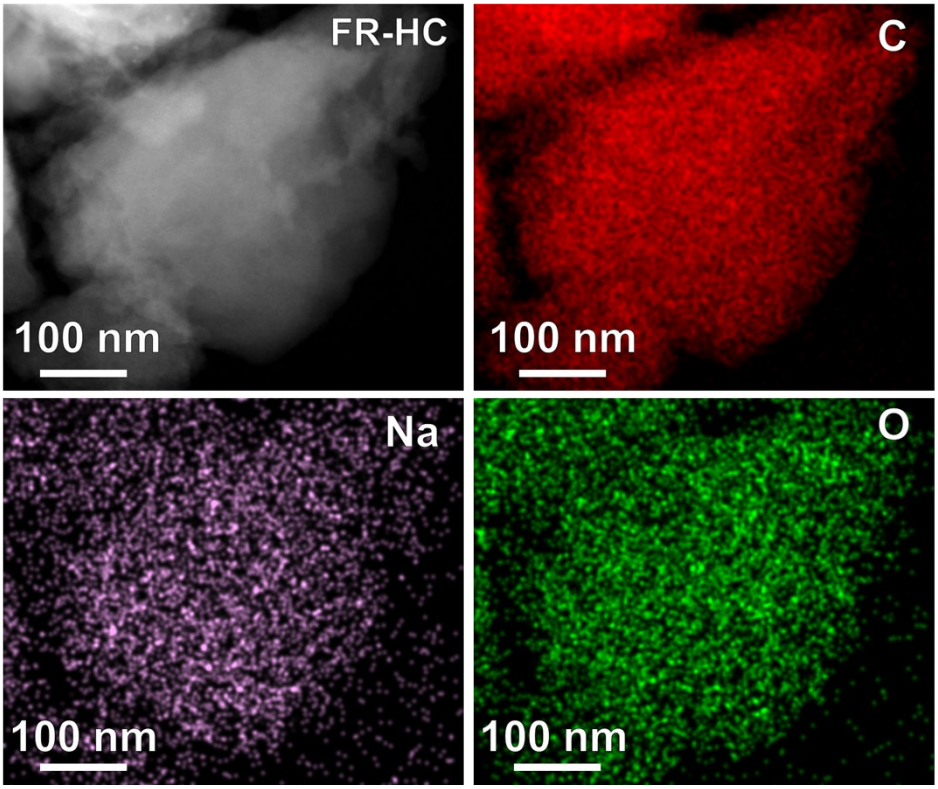

Fig. S9. TEM-EDS of FR-HC.

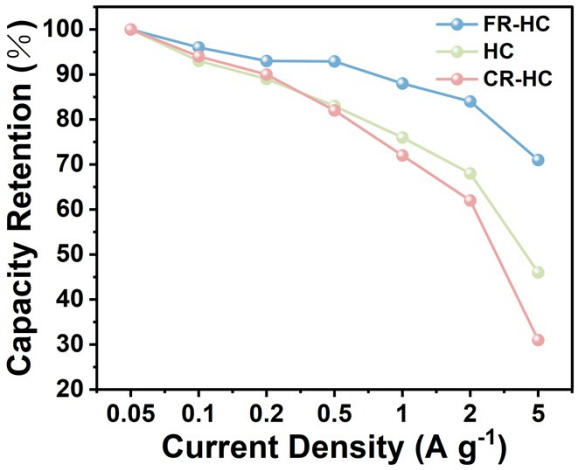

Fig. S10. Capacity retention ratio of different HC samples at various current densities.

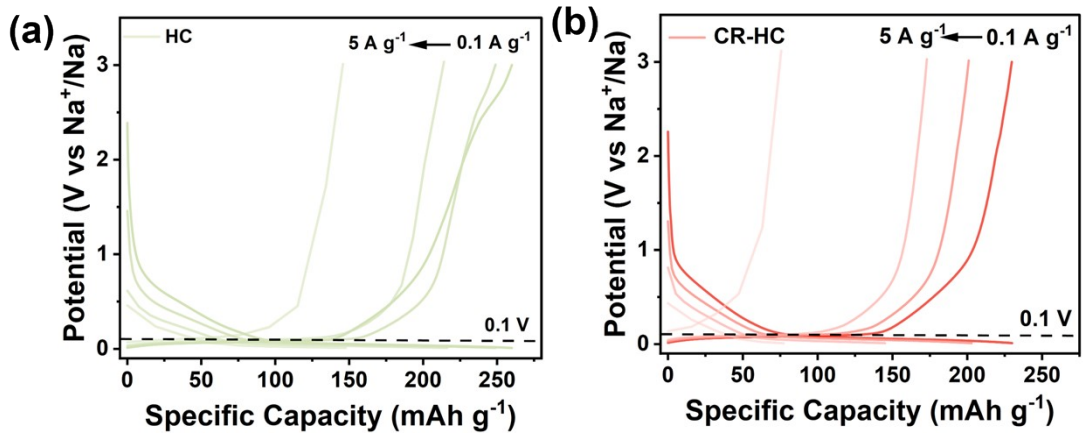

Fig. S11. Voltage profile of HC(a) and CR-HC (b) at different current densities.

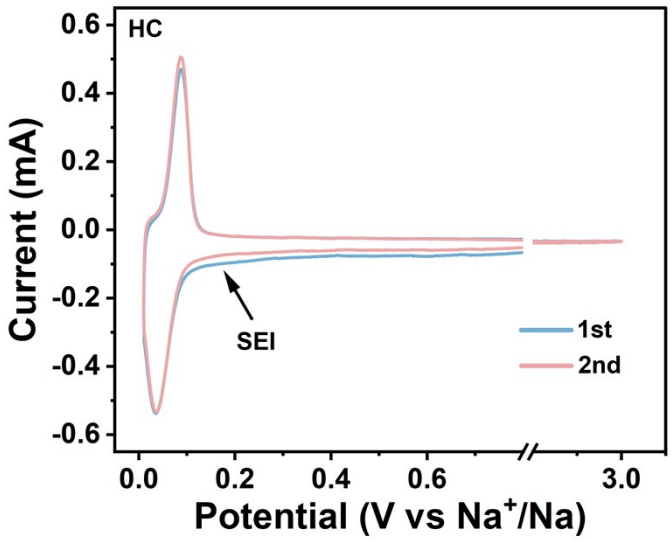

Fig. S12. The current voltage (CV) profiles of HC at a scan rate of 0.1 mV s^{-1}.

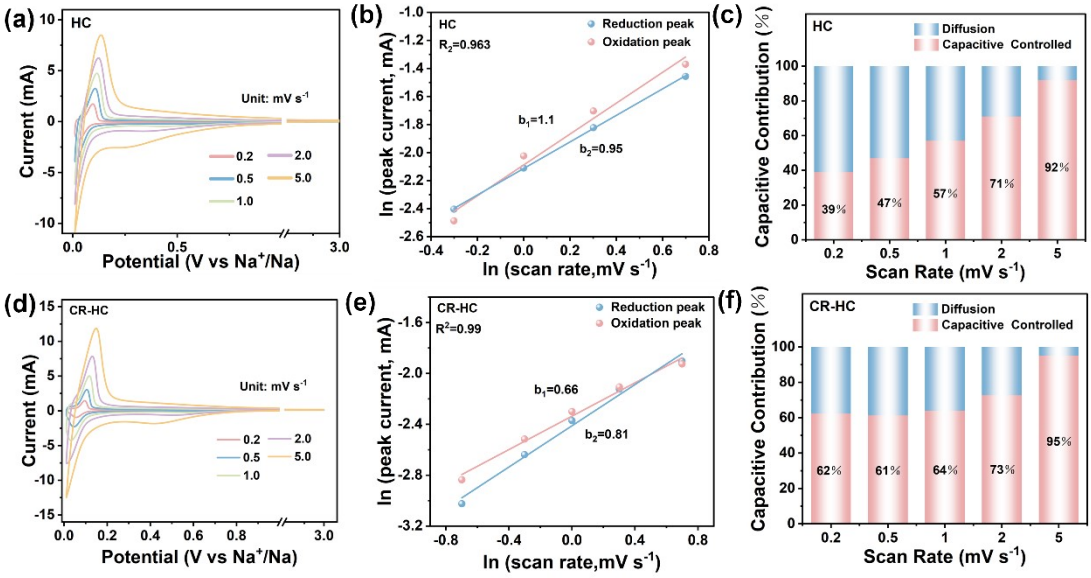

Fig. S13. a, d) The CV profiles of HC and CR-HC at diverse scan rates of 0.2-5.0 mV s^{-1}. b, e) The correlations of current scan rate (v) and peak current (i), which is calculated from oxidation peak and reduction peak. c, f) capacitive/diffusion contribution under various scan rates of HC and CR-HC.

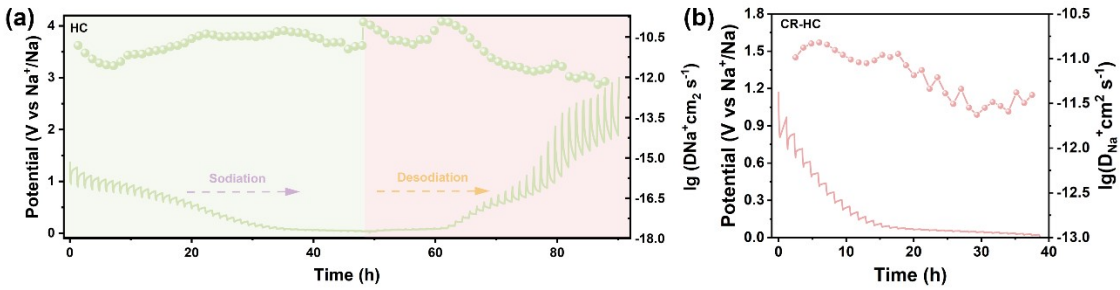

Fig. S14. a) The GITT profiles during the sodiation/disodiation process and the corresponding sodium-ions diffusion coefficients of HC. b) The GITT profiles during the sodiation process and the corresponding sodium-ions diffusion coefficients of CR-HC.

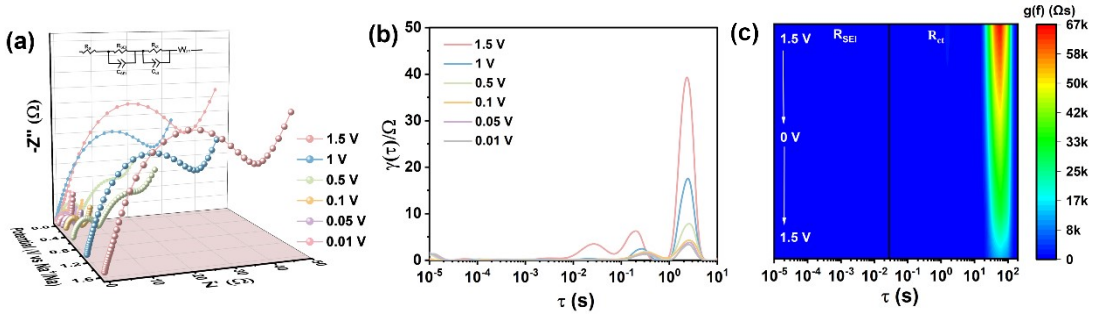

Fig. S15. a) The Nyquist plots of HC at different potentials during discharge process. b) The fitted DRT curves of HC during discharge process. c) The DRT transformation of in situ EIS spectra for the HC during discharge process.

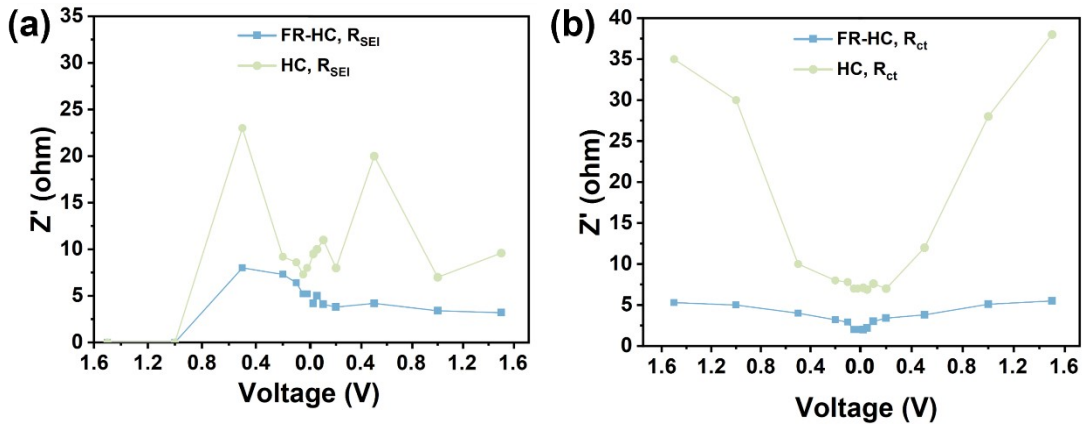

Fig. S16. a) The fitted a) R_{SEI} and b) R_{ct} of FR-HC and HC.

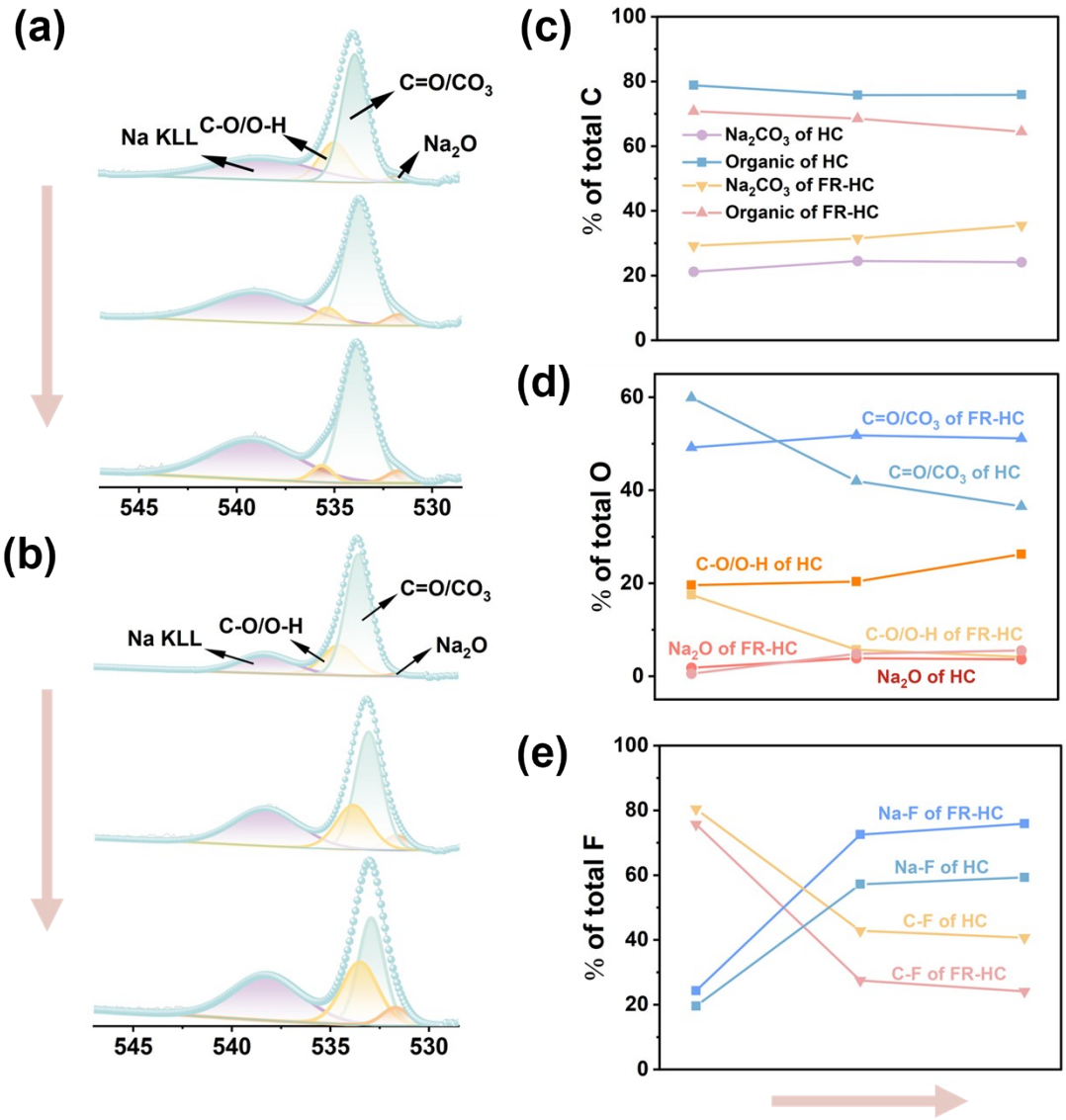

Fig. S17. a, b) The sputtering XPS spectra of O 1s for FR-HC and HC electrodes. c-e) The proportion of SEI components calculated from the C 1s, O 1s, and F 1s spectra.

Elements	Weight (%)	Atomic (%)
C	66.50	77.70
O	10.40	9.10
Na	8.70	5.30
P	9.47	4.3
F	4.93	3.6

Table S1. TEM-EDS of D-HC

Elements	Weight (%)	Atomic (%)
C	96.11	97.14
O	3.50	2.66
Na	0.38	0.20

Table S2. TEM-EDS of FR-HC

Parameter	Value
Cathode size	14.0 cm^2
Cathode areal loading	3.54 mg cm^{-2}
Cathode specific capacity	150 mAh g^{-1}
Total cell capacity	7.4 mAh
N/P ratio	1.3
Electrolyte volume	135 µL
E/C ratio	18.2 µL mAh^{-1}
Voltage window	1.8-3.8 V

Table S3. Full-cell configuration and electrochemical parameters.