Support information

Large scale synthesis of N–doped carbon spherical shells as high-performance cathode materials for Li–X (X=O_2, S, Se) batteries

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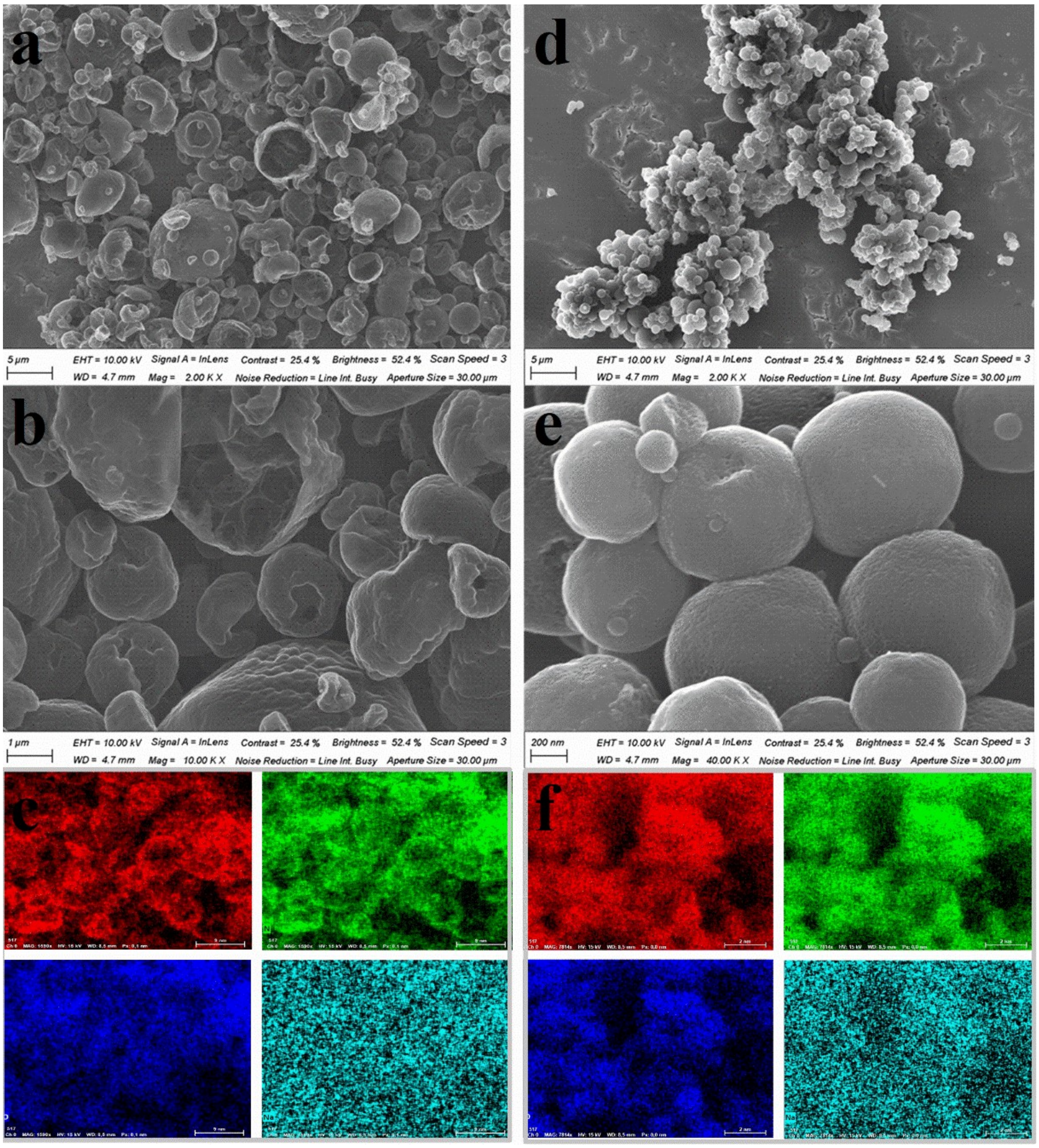


Figure S1. a, b) The SEM image, c) the element mapping of C-N; d, e) The SEM image, f) the element mapping of C-F.

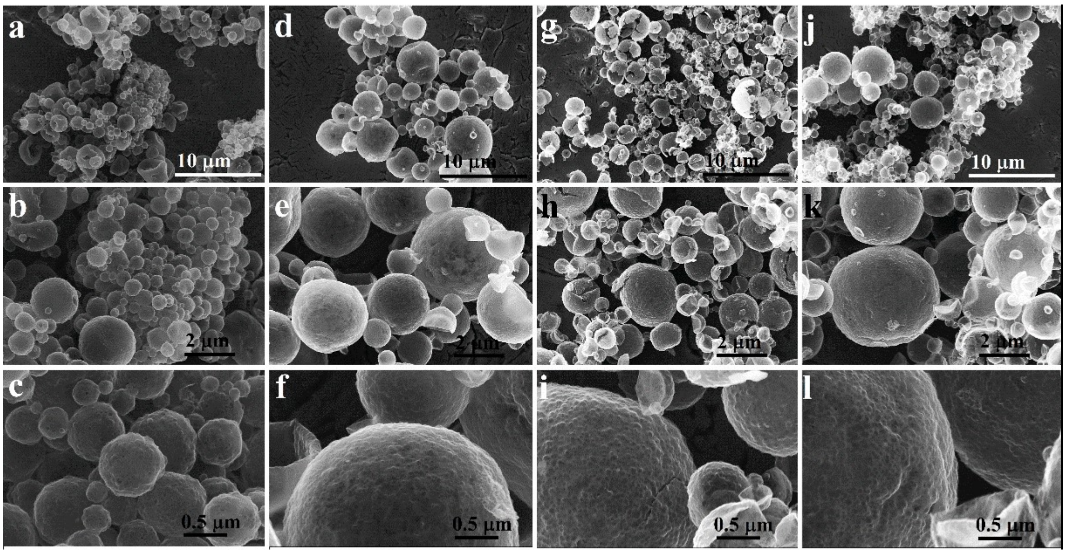


Figure S2. a, b, c) The SEM image of C-FN; d, e, f) C-$FN_{1/2}$; g, h, i)C-$FN_{1/4}$; j, k, l)C-$FN_{1/10}$.

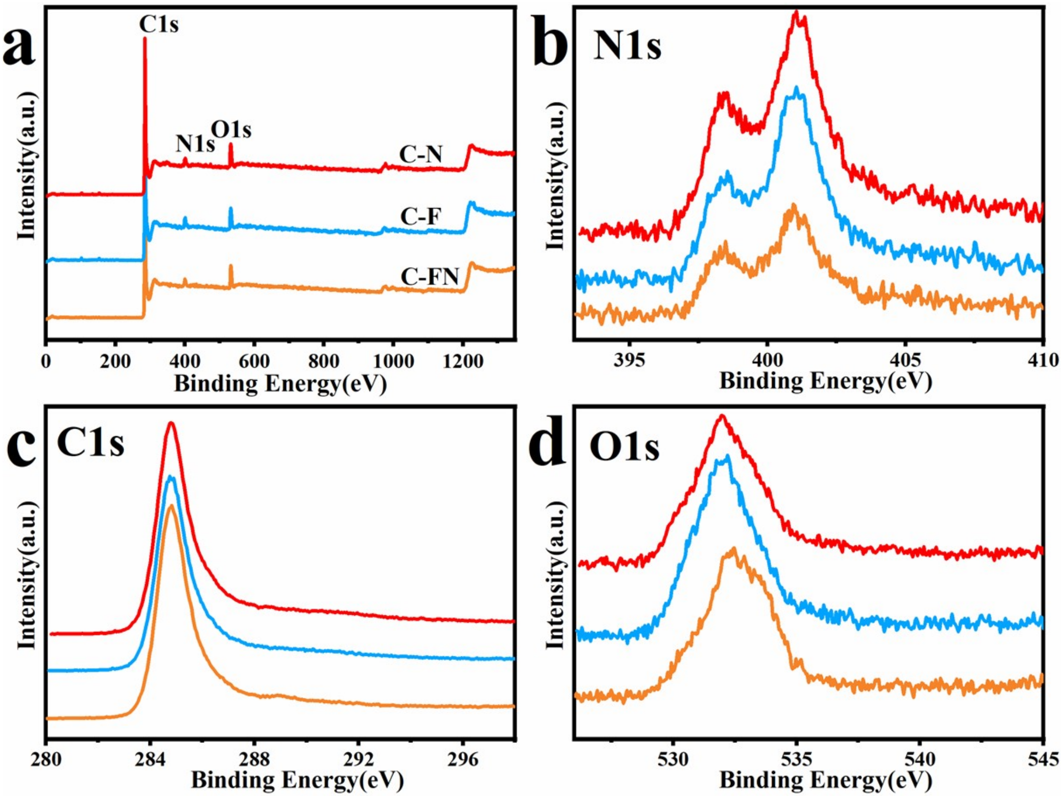


Figure S3. a) XPS survey spectra; b) high-resolution XPS of N 1s, c) C1s, d) O1s of C-F, C-N and C-FN.

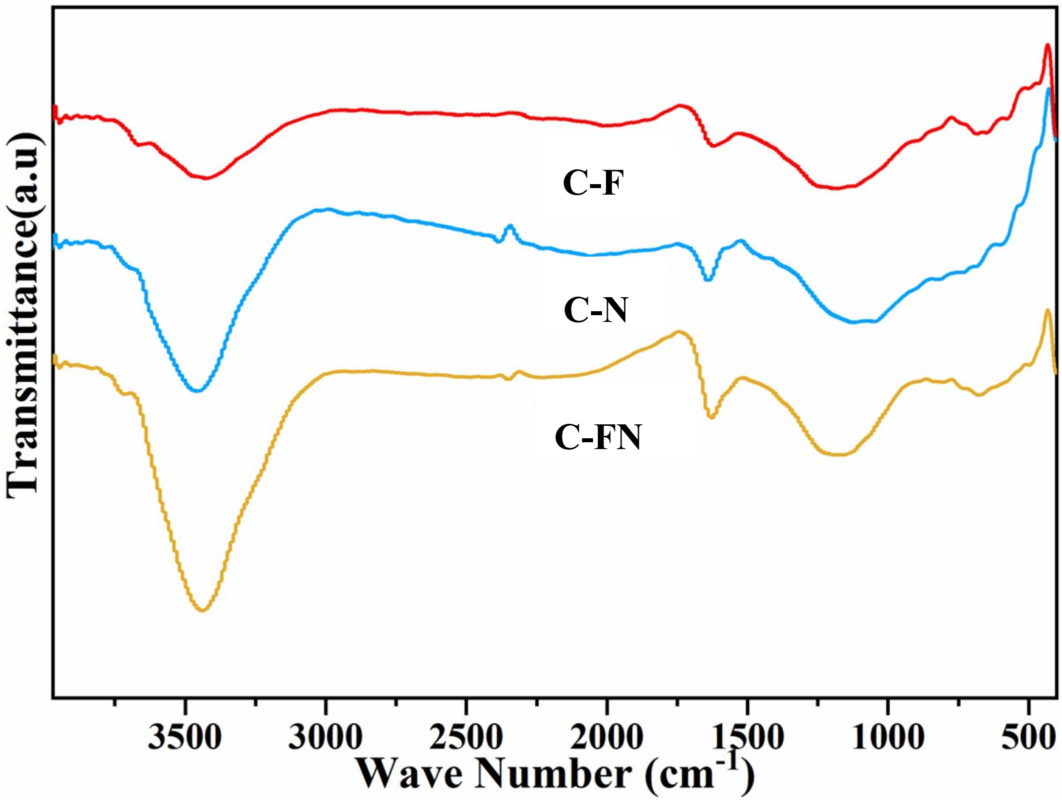
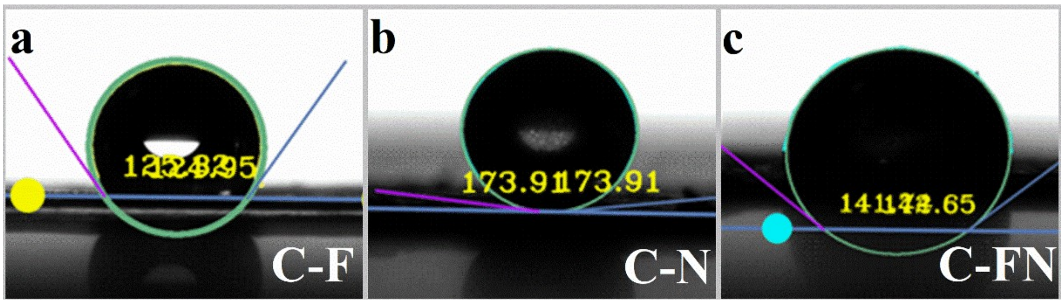


Figure S4. The Fourier Transform infrared reflection (FTIR) spectra of the prepared materials.



FigureS5. The water droplet contact angle on the surface of the Li-O cathode base on C-F, C-N and C-FN.

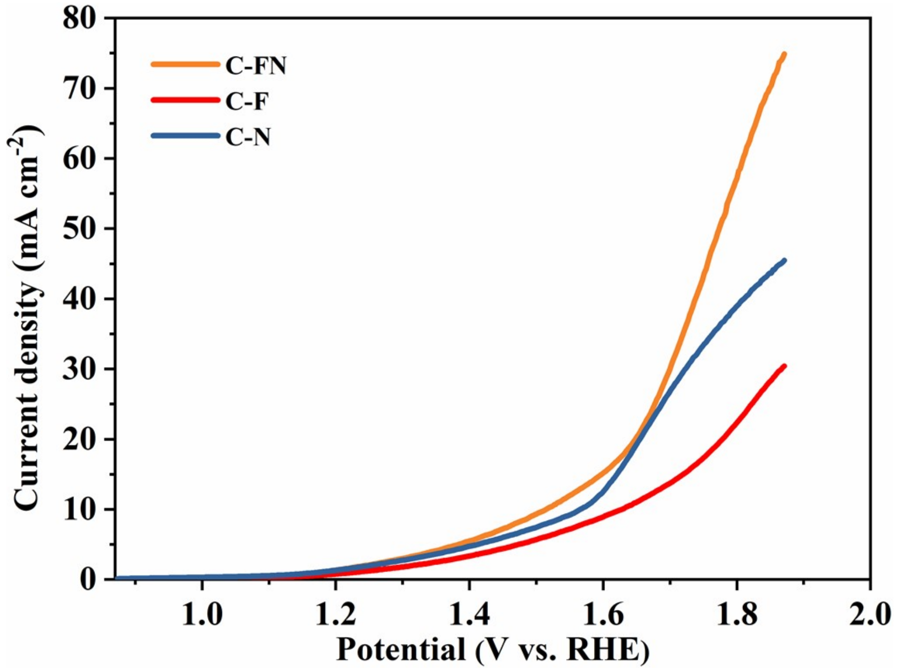


Figure S6. Linear sweep voltammetry (LSV) curves of the C-FN, C-F and C-N at 10 mA cm^{-2}.

Ion diffusion coefficient test

To further study the lithium-ion coefficient in the prepared cathodes, the D_{Li}^{+} can be calculated according to the following equation:

$$D_{Li^+} = \frac{R^2T^2}{2A^2n^4F^4C^2\sigma^2}$$

Where D_{Li}^{+} represents the lithium-ion diffusion coefficient ($cm^2\ s^{-1}$), R represents the gas constant (8.314 J $mol^{-1}K^{-1}$), T represents the absolute temperature (298.15 K), A represents the electrode area, n represents the number of electrons involved in the redox process, C represents the shuttle concentration, F represents the Faraday constant (96500 C mol^{-1}), and σ represents the Warburg factor ($\Omega\ s^{-1/2}$), which is obtained from the following equation: $-Z''=\sigma\omega^{-1/2}$. To get σ, the electrochemical impedance spectroscopy (EIS) measurements were measured by CHI760e electrochemical workstation (CH, Shanghai, China) with the frequency ranging from 10^{-2} to 10^{5} Hz with an alternating current amplitude of 5 mV.

Furthermore, galvanostatic intermittent titration (GITT) profiles were tested. The loading mass of Lithium-selenium cathode and Li-S cathode is 0.7mg and 1.2mg respectively. Each step was composed of 10 min discharge or charge pulse at a current density of 0.1 A g^{-1}, followed by 1 hour of shelved. The Li ion diffusion coefficient is calculated by the following equation:

$$D_{Li^+} = \frac{4}{\Pi\tau}\left(\frac{m_B}{\rho S}\right)^2\left(\frac{\Delta E_s}{\Delta E_t}\right)^2$$

ΔE_s between two equilibrium potentials, and ΔE_t is the difference between the potentials before and after the pulse. Where S stand for the area of contact between electrode and electrolyte, τ is the constant current pulse time, m_B is the active mass, ρ is the density of active material.

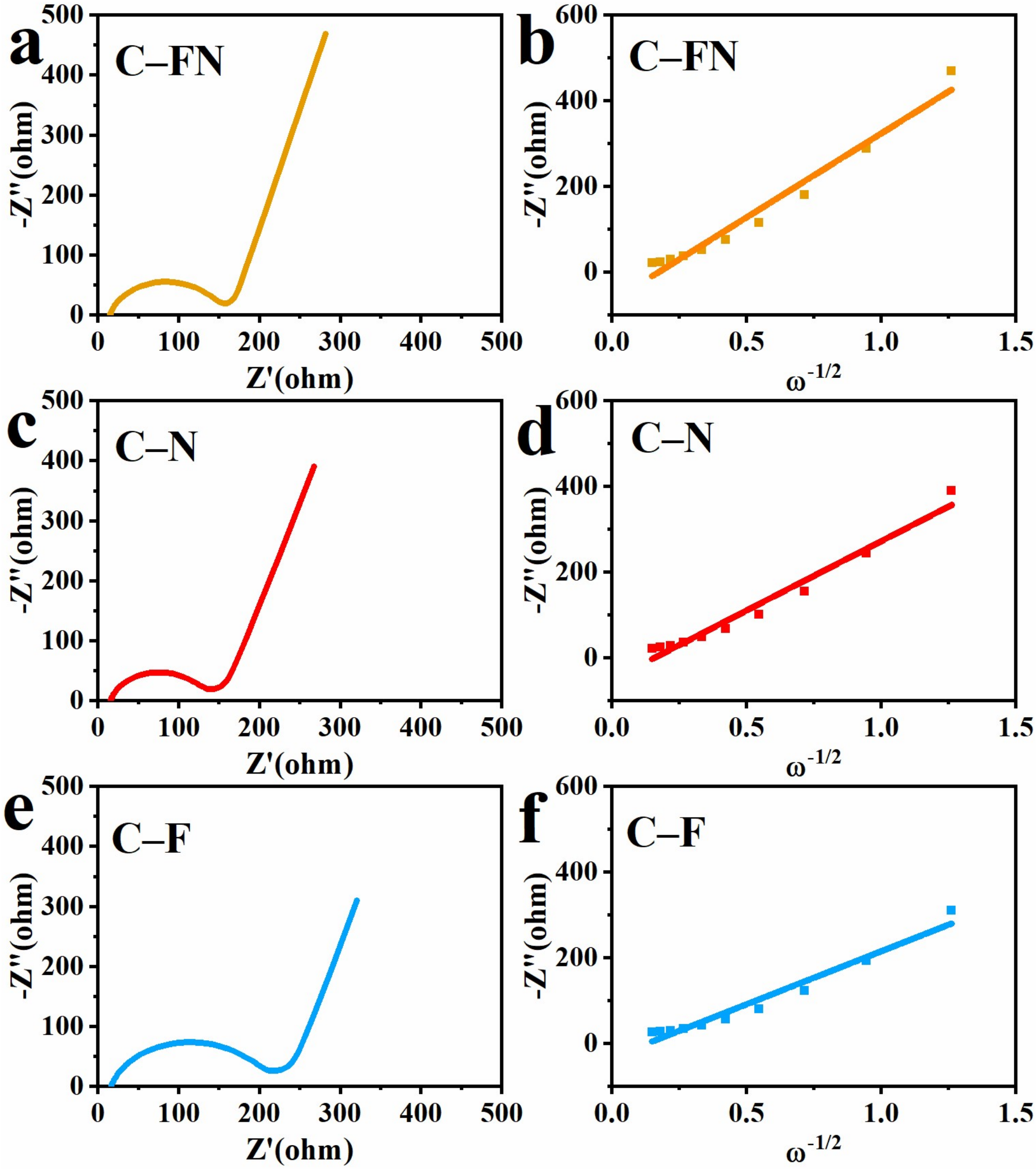


Figure S7 (a, c and e) The EIS spectra and (b, d and f) the relationship lines between Z″ and $\omega^{-1/2}$ in the low frequency of Li-O2 batteries base on C-FN, C-N and C-F cathodes.

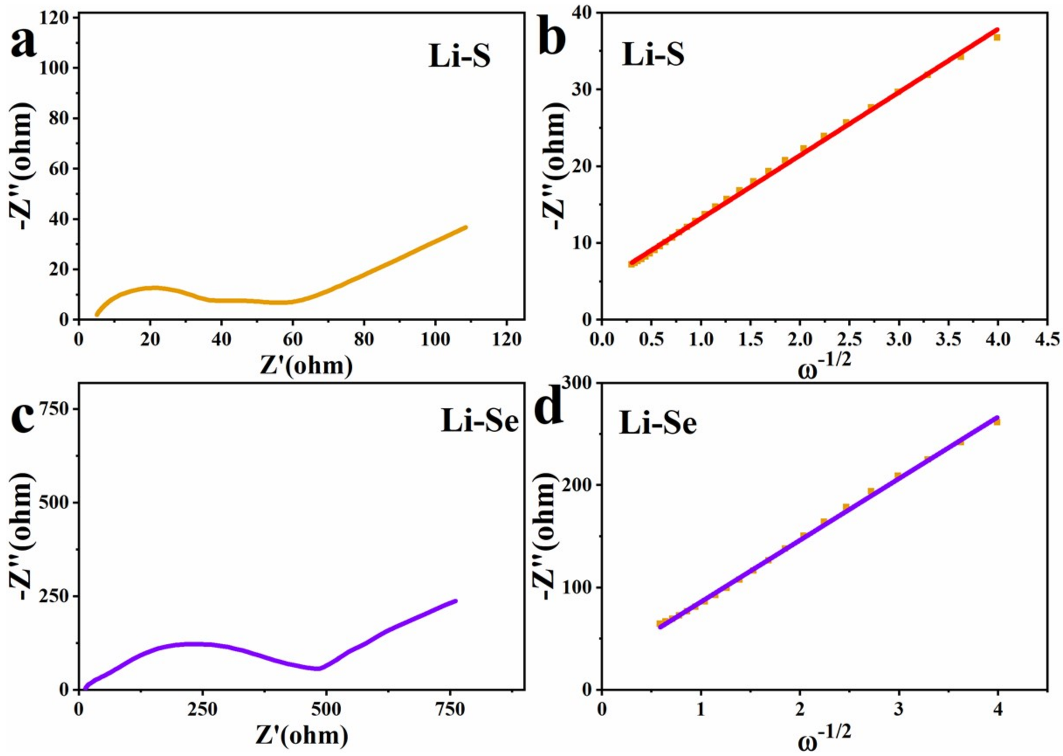


Figure S8 (a, and c) The EIS spectra and (b and d) the relationship lines between Z″ and ω−1/2 in the low frequency of Li-S and Li-Se batteries.

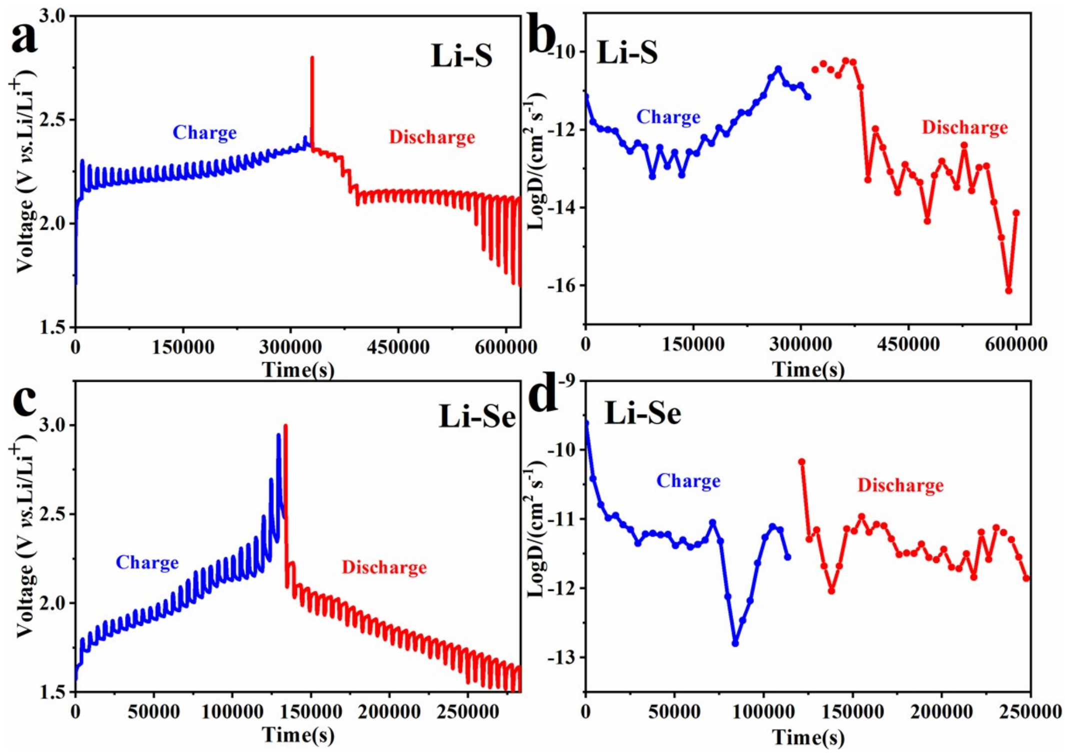


Figure S9 GITT curves and diffusion coefficient of Li-S battery (a and b) and Li-Se battery (c and d)

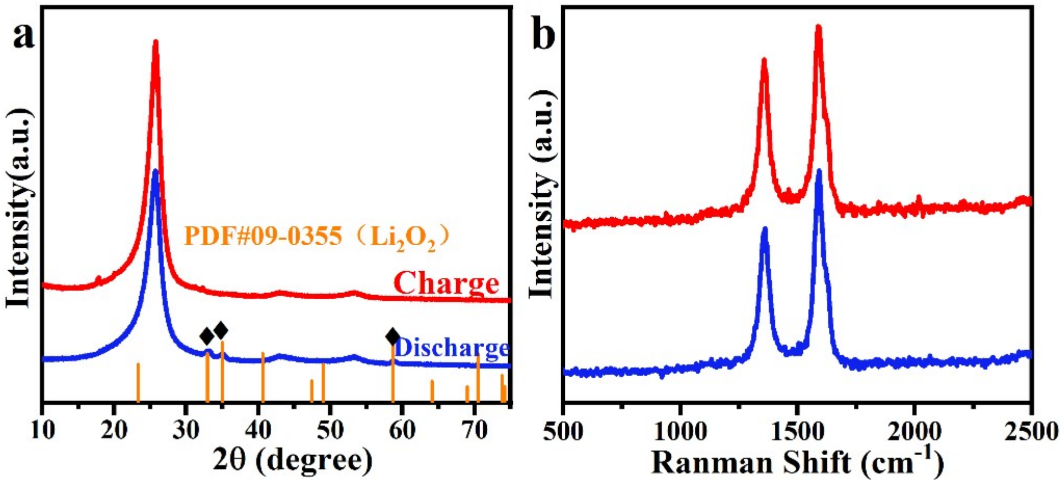


Figure S10 (a) XRD and (b) Raman patterns of C-FN based Li-O_2 battery cathodes at full charge and discharge stages.

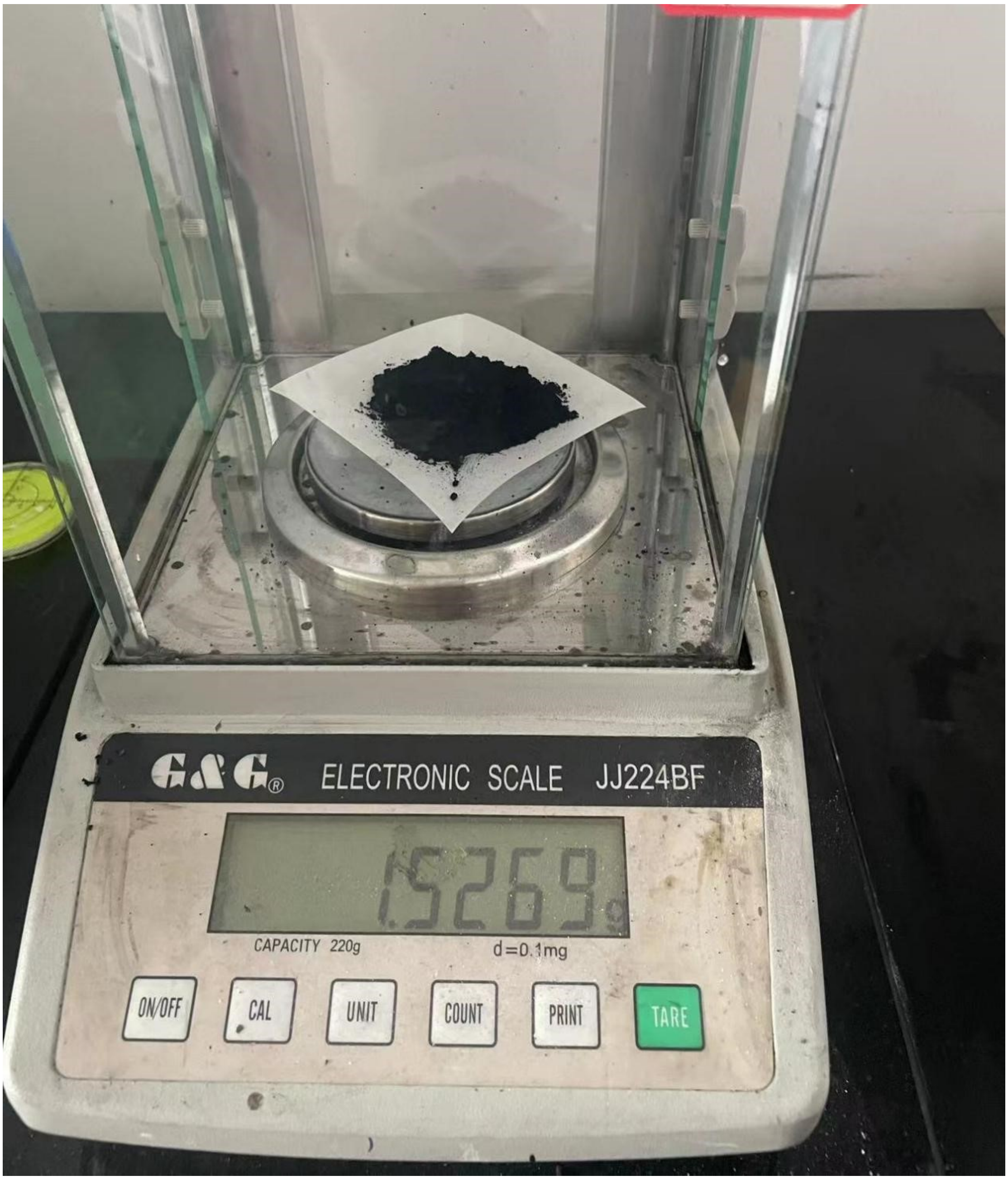


Figure S11.The photograph of 1.5 g C-FN.