

## Supporting Information

### Stable Li metal anode in a lithiophilic shuttle

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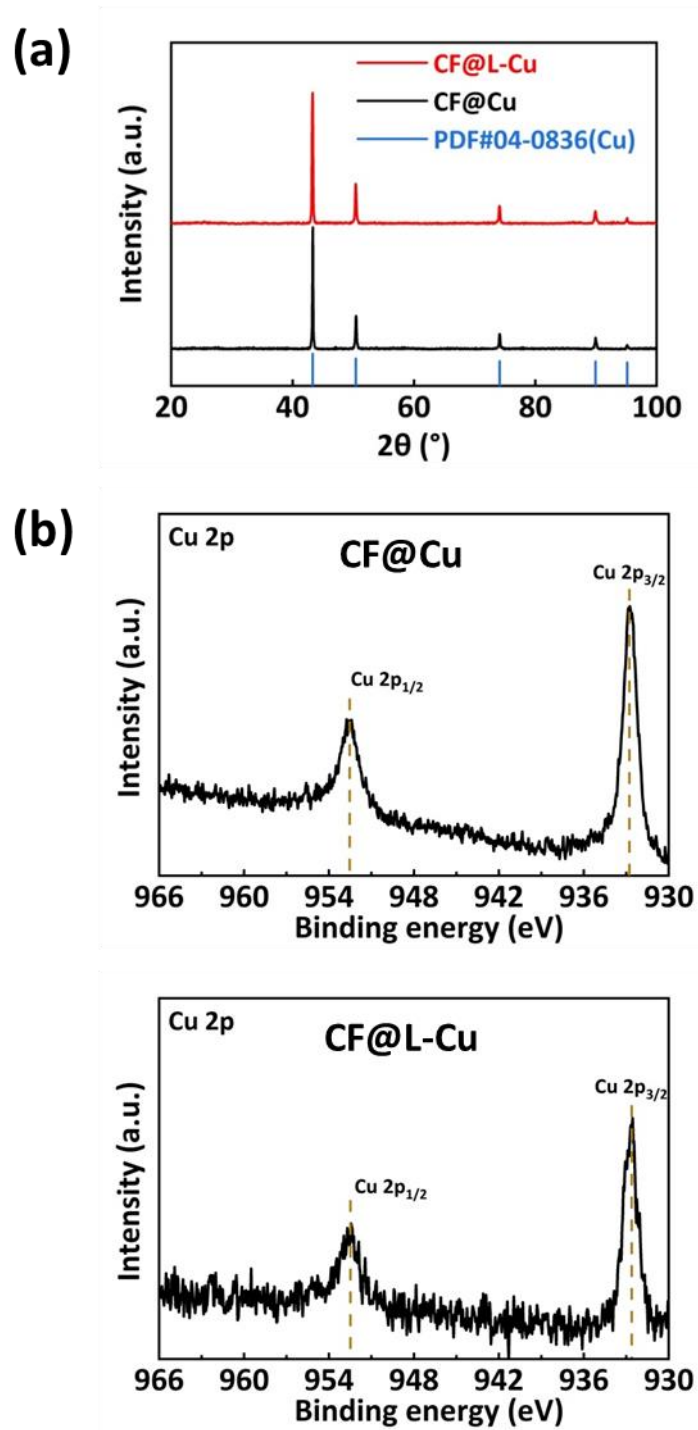
c. 21C Innovation Laboratory, Contemporary Amperex Technology Ltd. (CATL), Ningde 352100, China.

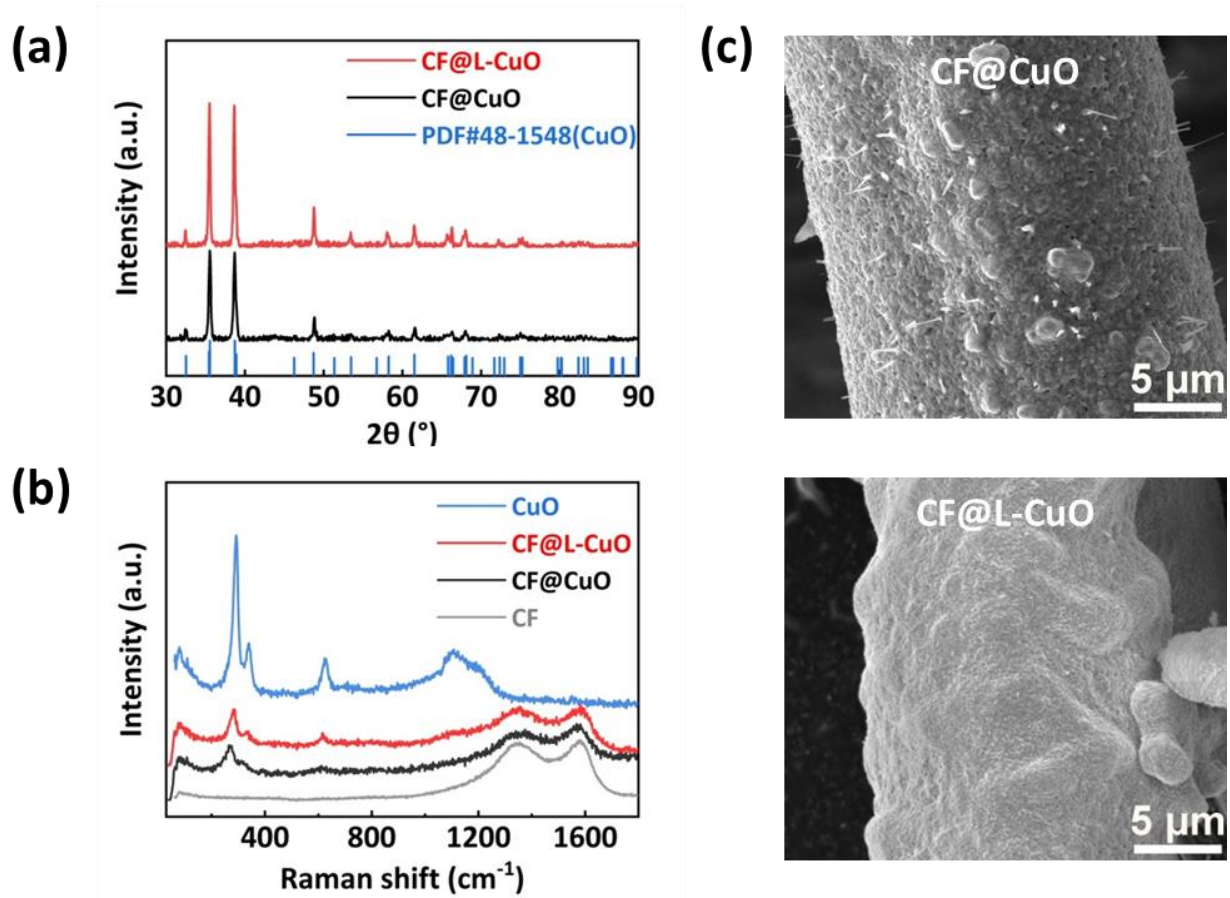
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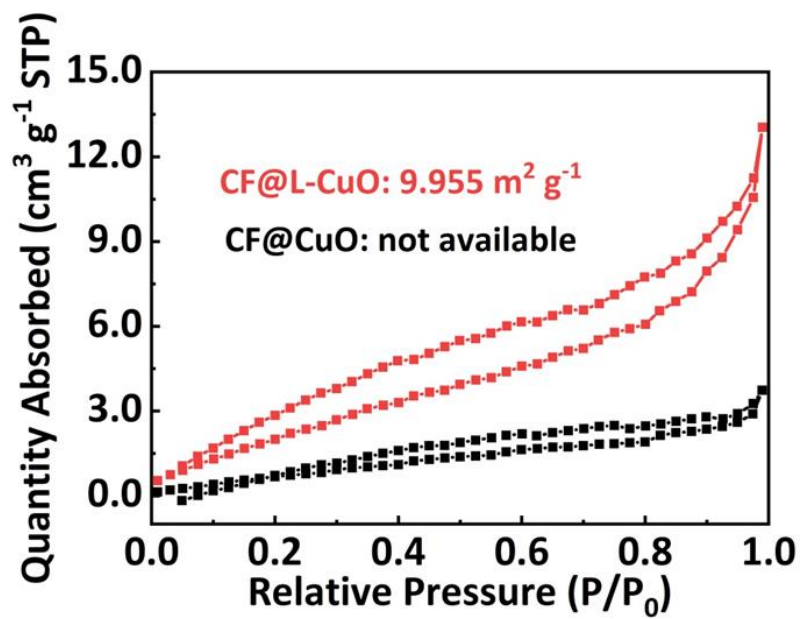
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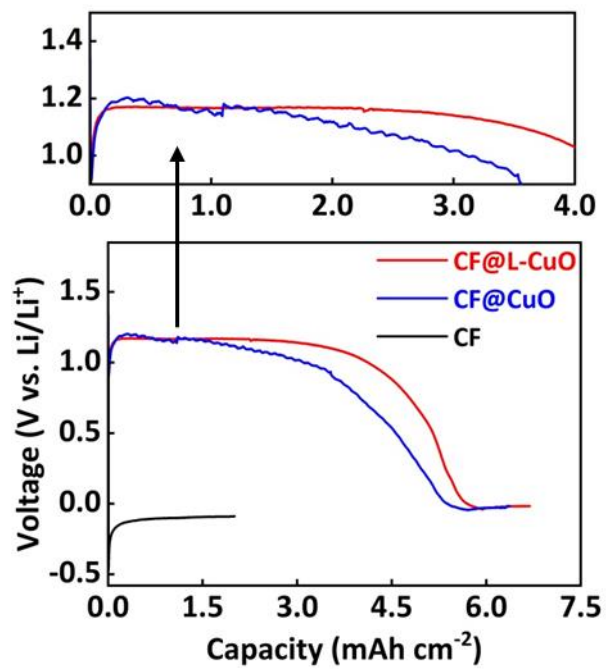




**Figure S2.** (a) XRD patterns, (b) Raman spectra and (c) SEM images of CF@CuO and CF@L-CuO.



**Figure S3.** N<sub>2</sub> adsorption isotherm of CF@CuO and CF@L-CuO from BET measurements.



**Figure S4.** Voltage profiles of Li plating on CF, CF@CuO and CF@L-CuO.

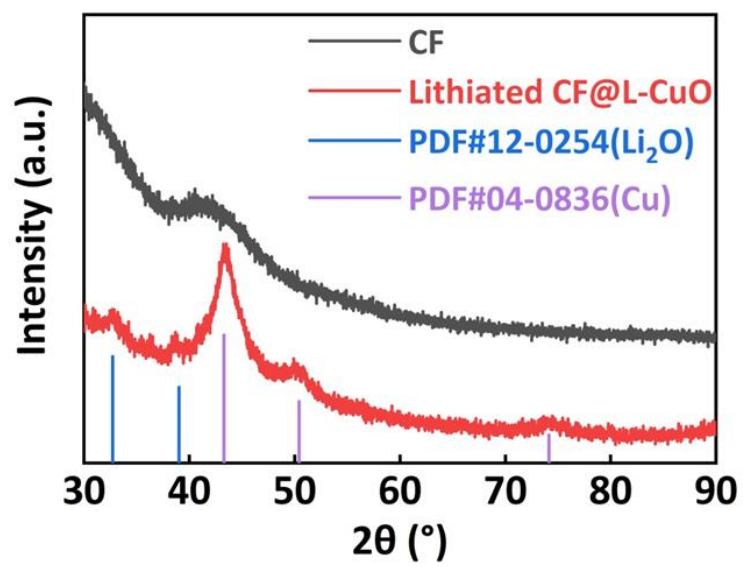
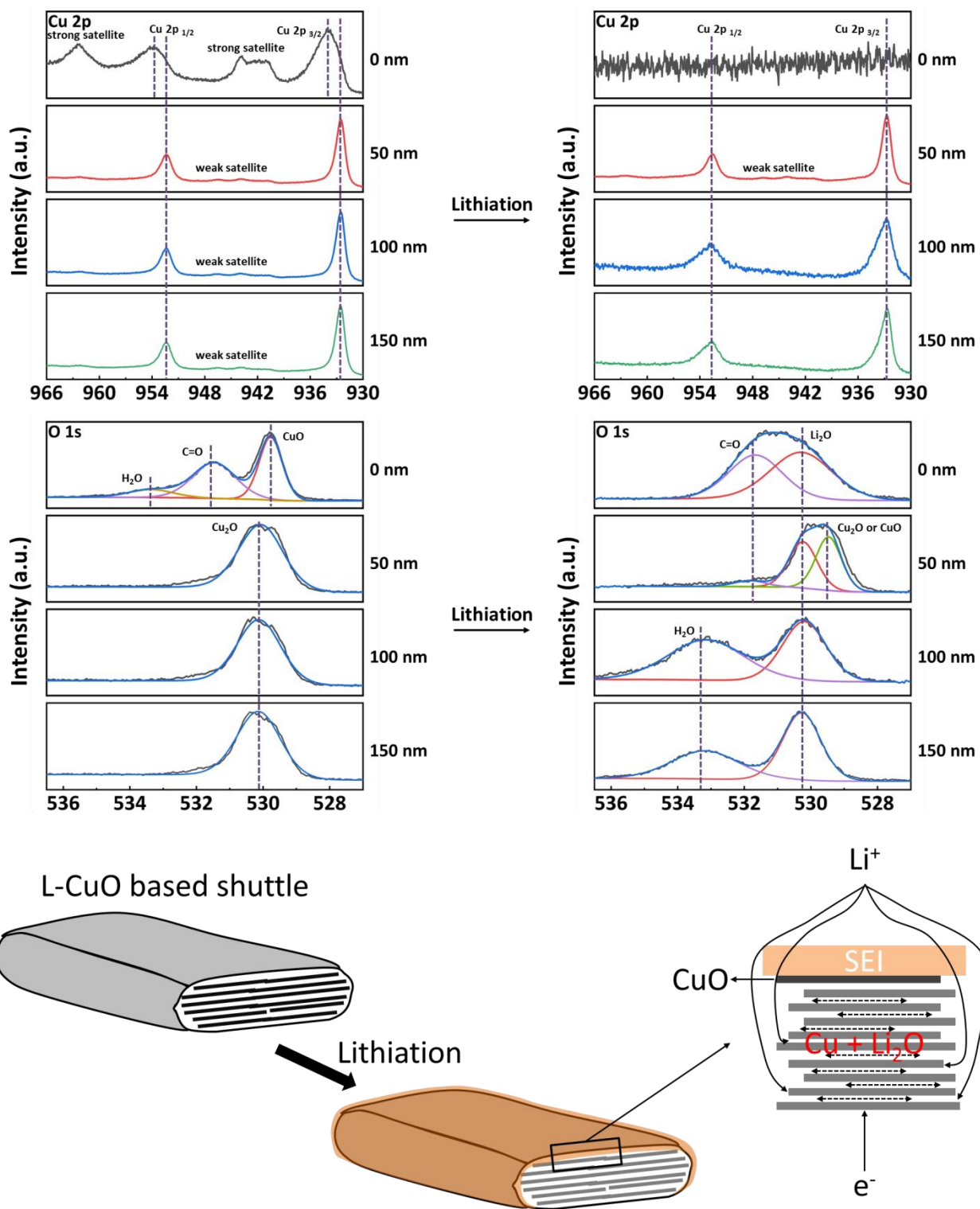
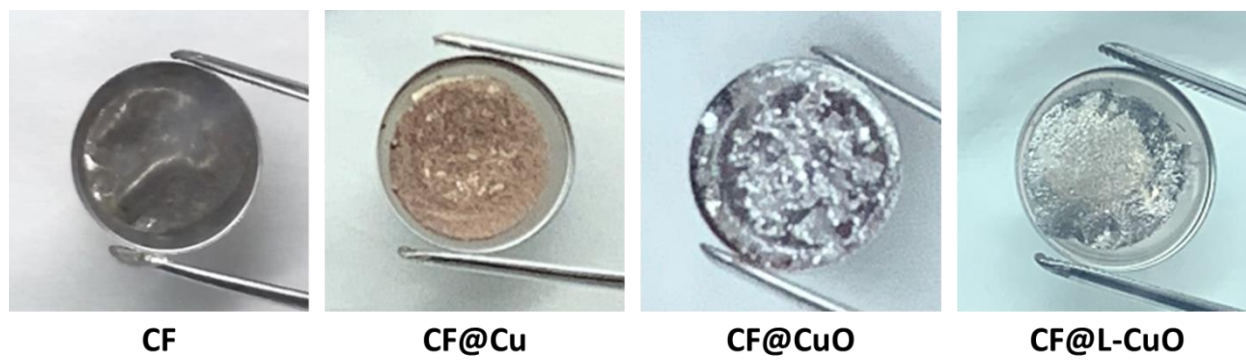


Figure S5. XRD pattern of the lithiated CF@L-CuO.

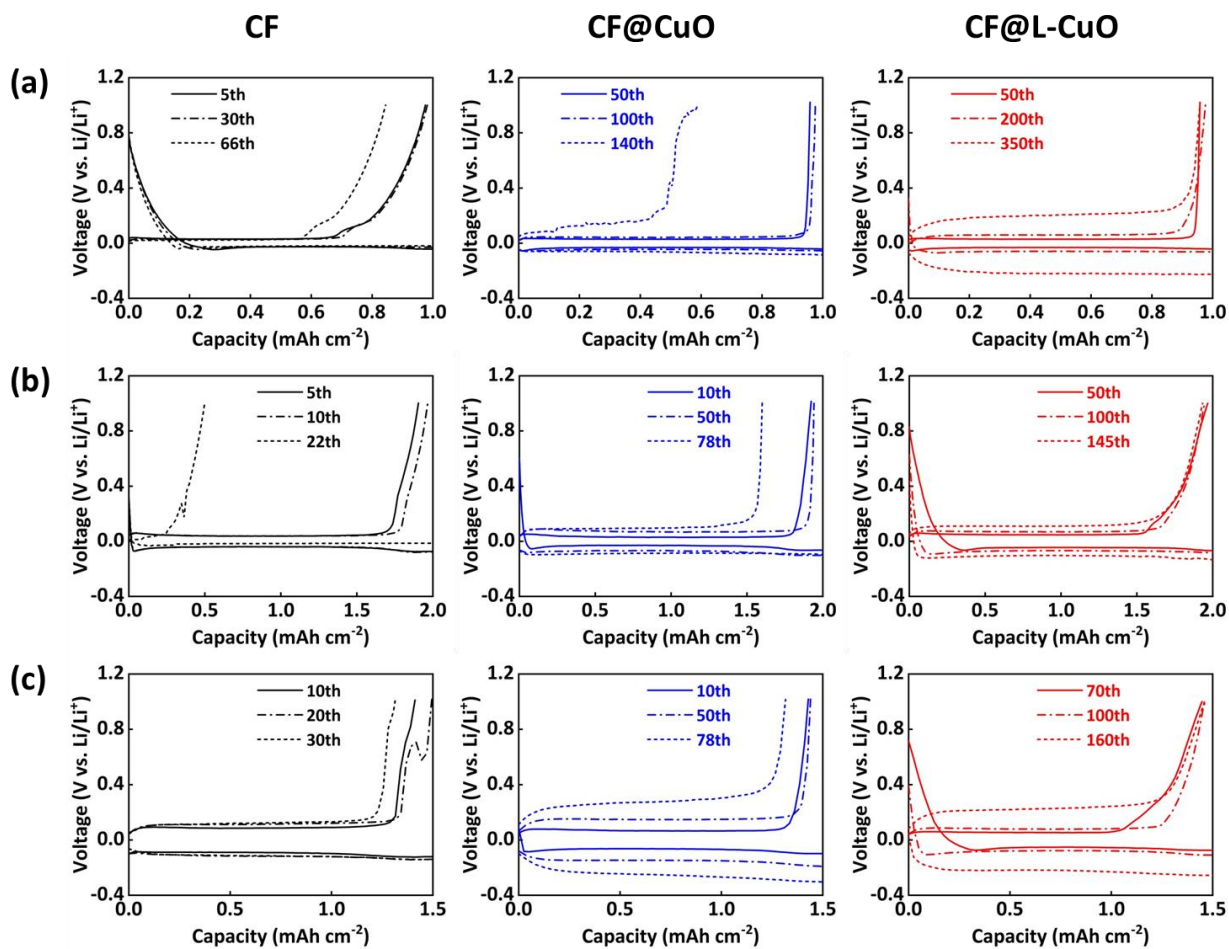


**Figure S6.** Cu 2p and O 1s XPS spectra of CF@L-CuO before and after lithiation process.

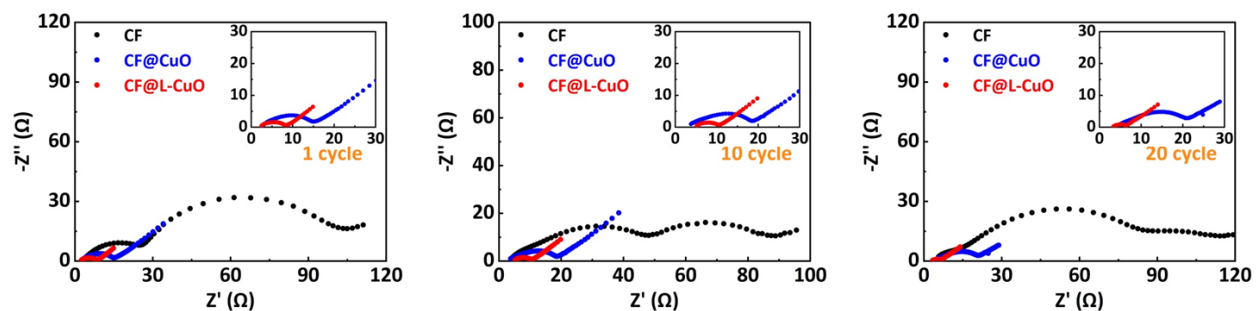


**Figure S7.** Digital photos of CF, CF@Cu, CF@CuO and CF@L-CuO deposited on molten Li.

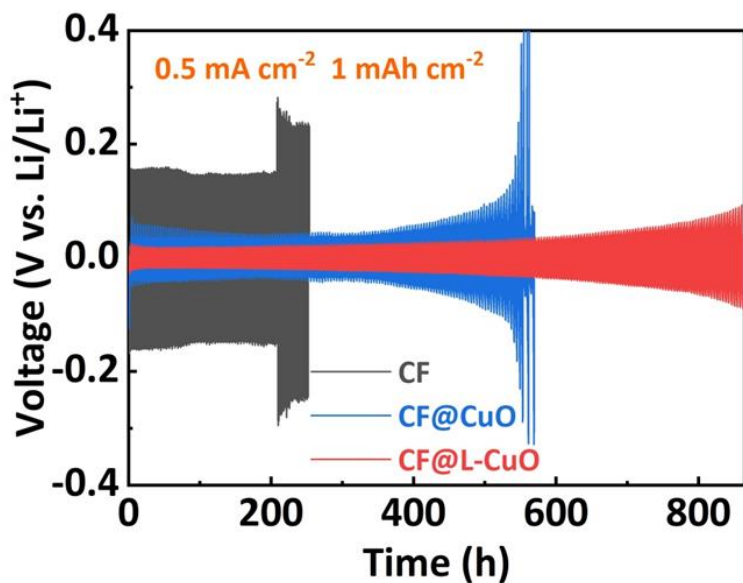




**Figure S8.** Discharge/charge curves of Li plating/stripping of Li metal half cells using CF, CF@CuO or CF@L-CuO as working electrodes, under (a)  $0.5 \text{ mA cm}^{-2} - 1 \text{ mAh cm}^{-2}$ , (b)  $1 \text{ mA cm}^{-2} - 2 \text{ mAh cm}^{-2}$  and (c)  $3 \text{ mA cm}^{-2} - 1.5 \text{ mAh cm}^{-2}$ .

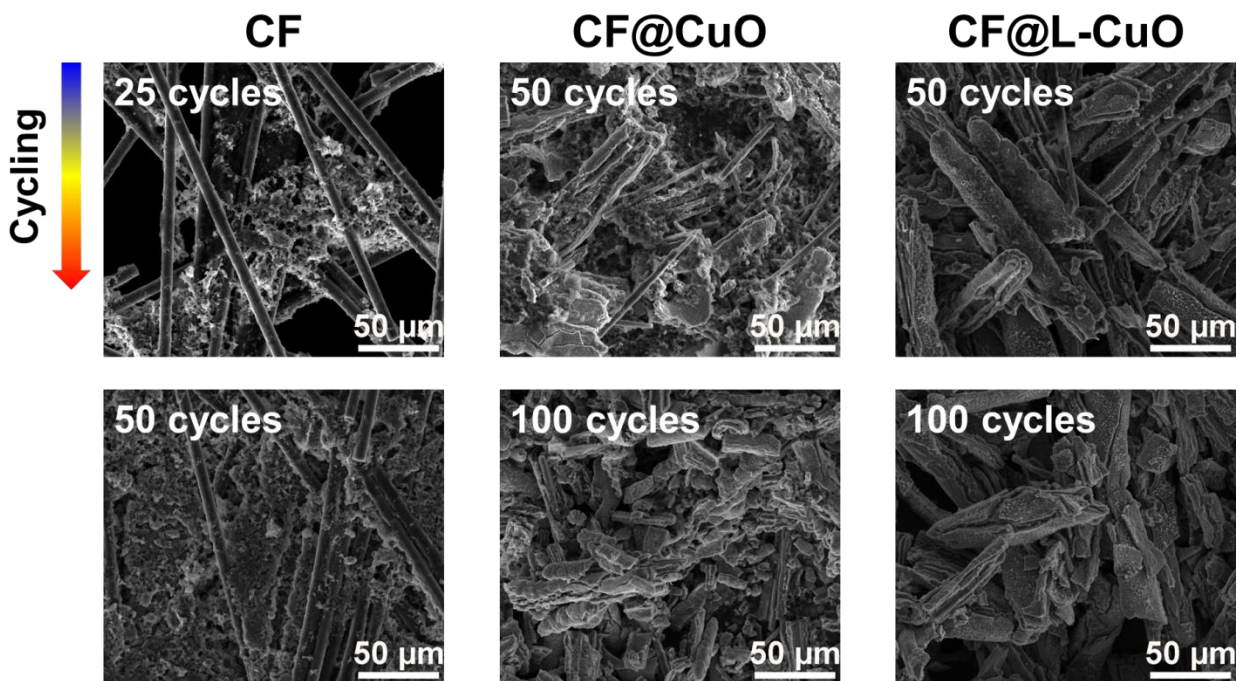


**Figure S9.** Nyquist plots from EIS data of CF, CF@CuO and CF@L-CuO at different cycling states. The cycling was carried out under  $0.5 \text{ mA cm}^{-2} - 1 \text{ mAh cm}^{-2}$ .

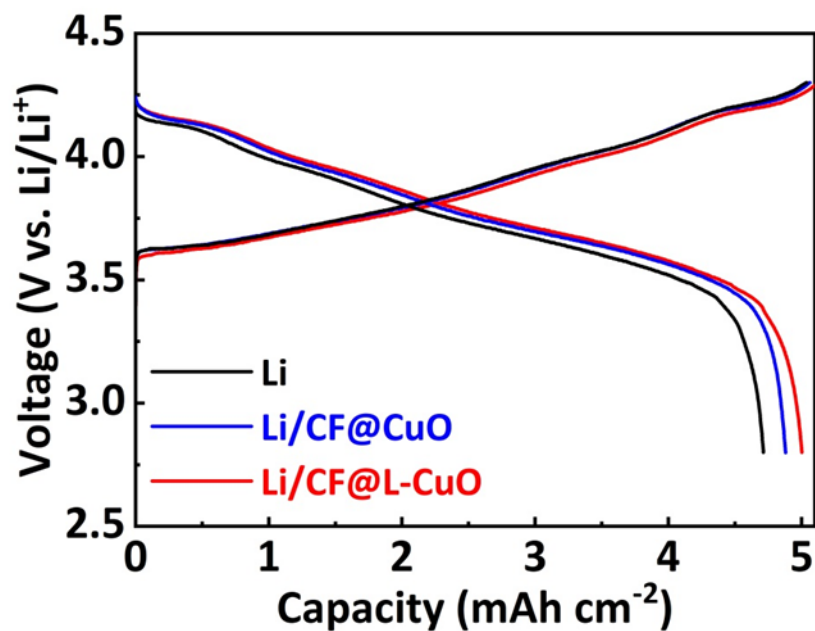


**Figure S10.** Voltage profiles of Li/CF||Li/CF, Li/CF@CuO||Li/CF@CuO and Li/CF@L-CuO||Li/CF@L-CuO symmetrical cells cycling at  $0.5 \text{ mA cm}^{-2}$  for a fixed capacity of  $1 \text{ mAh cm}^{-2}$ .

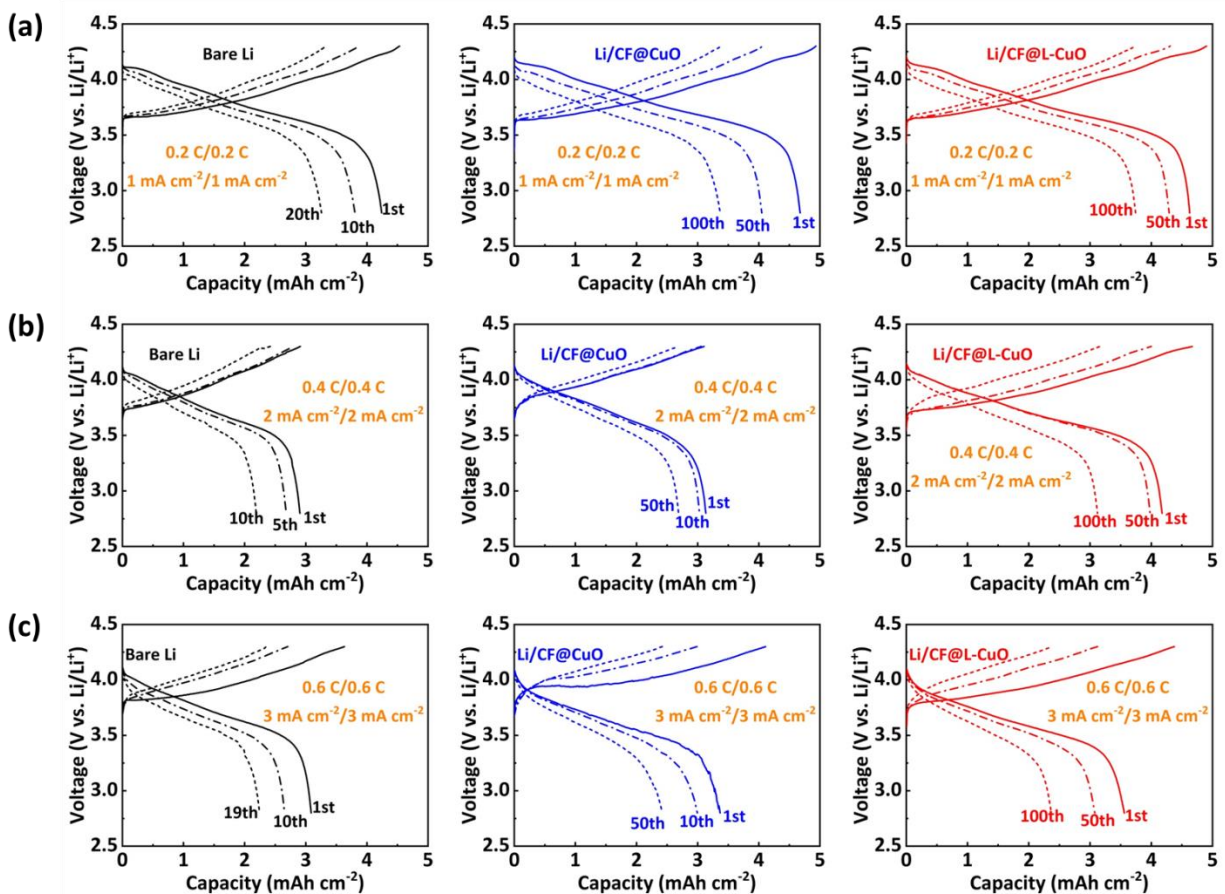
2.



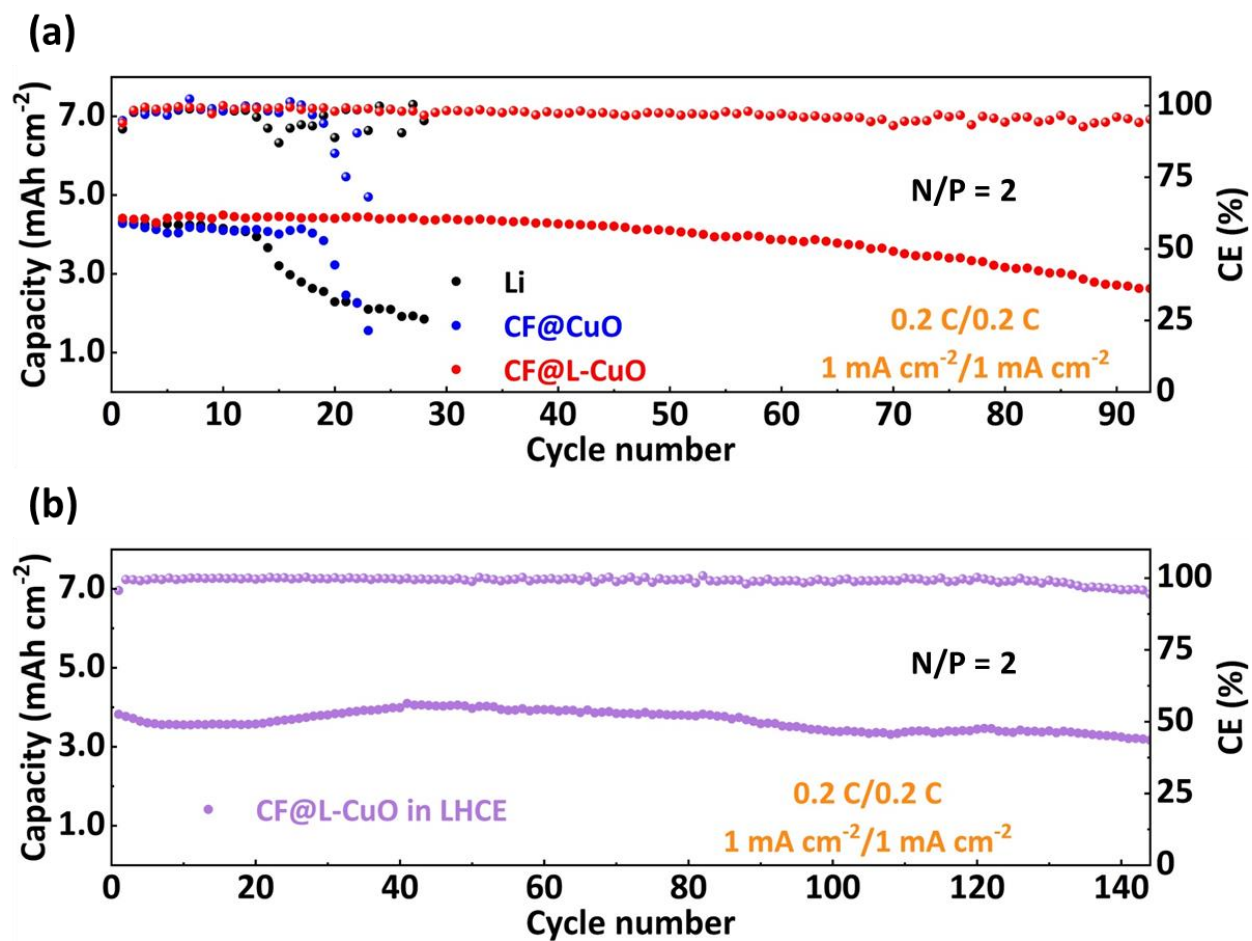
**Figure S11.** SEM images of CF, CF@CuO and CF@L-CuO disassembled from the half cells at different cycling states. The cycling was carried out under  $0.5 \text{ mA cm}^{-2} - 1 \text{ mAh cm}^{-2}$ .



**Figure S12.** Charge/discharge curves of Li metal full cells using Li, Li/CF@CuO or Li/CF@L-CuO anodes and NCA cathodes ( $\sim 5 \text{ mAh cm}^{-2}$ ), at charge/discharge rates of 0.1C/0.1C ( $0.5 \text{ mA cm}^{-2}/0.5 \text{ mA cm}^{-2}$ ).



**Figure S13.** Charge/discharge curves of Li metal full cells using Li, Li/CF@CuO or Li/CF@L-CuO anodes and NCA cathodes ( $\sim 5 \text{ mAh cm}^{-2}$ ), at charge/discharge rates of (a) 0.2C/0.2C ( $1 \text{ mA cm}^{-2}/1 \text{ mA cm}^{-2}$ ), (b) 0.4C/0.4C ( $2 \text{ mA cm}^{-2}/2 \text{ mA cm}^{-2}$ ) and (c) 0.6C/0.6C ( $3 \text{ mA cm}^{-2}/3 \text{ mA cm}^{-2}$ ).



**Figure S14.** Cycling performances of Li metal full cells using NCA cathodes ( $\sim 5 \text{ mAh cm}^{-2}$ ) with an N/P ratio of 2, in (a) carbonate electrolyte and (b) LHCE. The cycling test was carried out at charge/discharge rates of 0.2C/0.2C ( $1 \text{ mA cm}^{-2}/1 \text{ mA cm}^{-2}$ ).