Electronic Supplementary Information (ESI)

Bi(nanoparticles)/CN_x(nanosheets) nanocomposites as high capacity and stable electrode materials for supercapacitors: the role of urea

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Section "Electrochemical tests"

The specific capacitance (S_c) value of BU-C/NF and NiLH-C/NF electrodes were calculated from the galvanostatic charge-discharge GCD curves according to the following equation:

$$S_c = (I \cdot \Delta t)/(m \cdot \Delta V), \quad \text{(S1)}$$

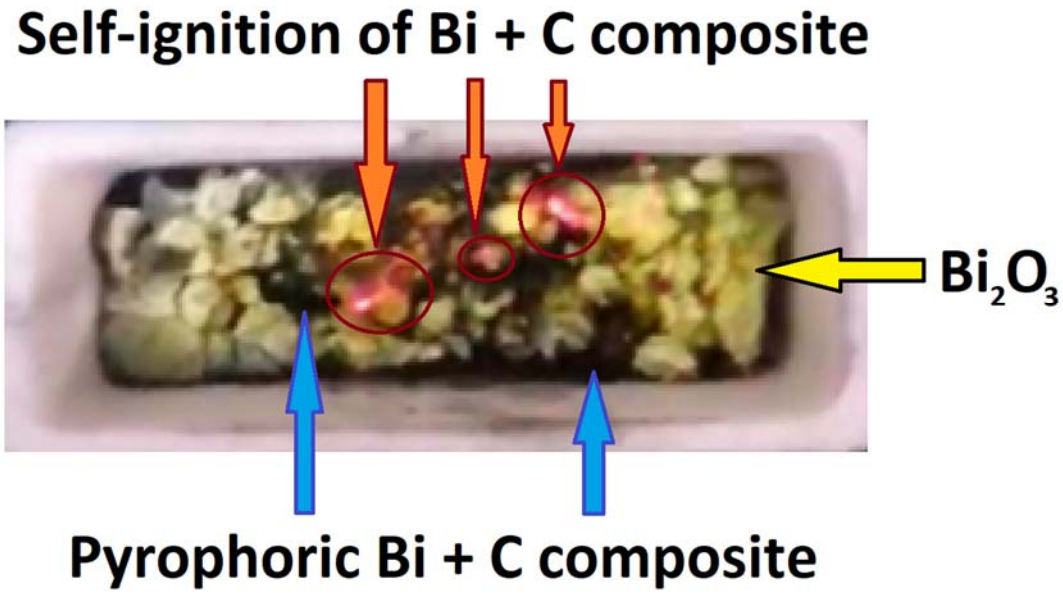
where $I$is the discharge current, Δt is discharge time, m is the mass of the active material and ΔV is the potential window.

The energy density (S_E) and power density (S_P) of BU-C/NF//NiLH-C/NF supercapacitor was calculated using the following equations:

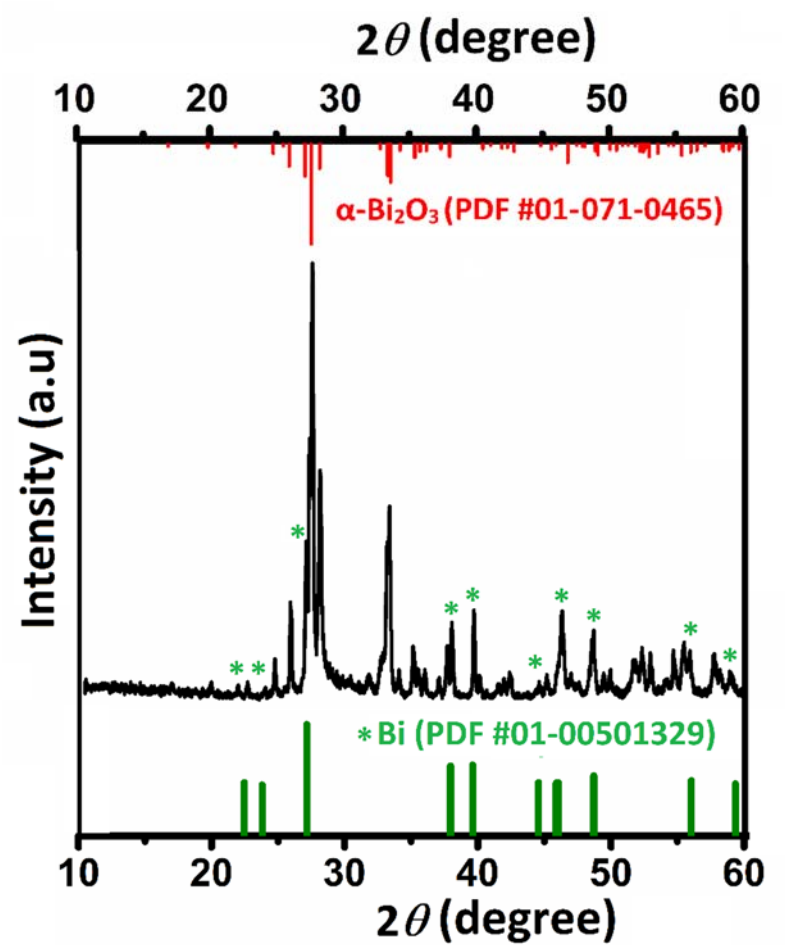
$$S_E = (S_c \cdot \Delta V^2)/7200 \quad \text{(S2)}$$

$$S_P = (3600 \cdot S_E)/\Delta t \quad \text{(S3)}$$

The electrochemical cell EQ-STC15 (used to test model supercapacitor of BU-C/NF//NiLH-C/NF) has the following features: cell is made full stainless steel SS304; cell thickness 6 mm (cathode + separator + anode), working electrode diameter 15 mm; 6 mm height spacer inside the test cell to press down on the electrode and prevent the electrode from curling; sealed by electrolyte corrosive-proof PTFE O-rings; anti-corrosive Au coating on the cell contacts and inserts.



(a)



(b)

Figure S1. (a) Spontaneous combustion of the Bi + C composite when exposed to air (sample obtained by annealing pure Bi(cit) at 700 °C in argon atmosphere) and (b) XRD data after oxidation of bismuth and carbon in air (residual amount of metallic bismuth is less than 15 %wt.).

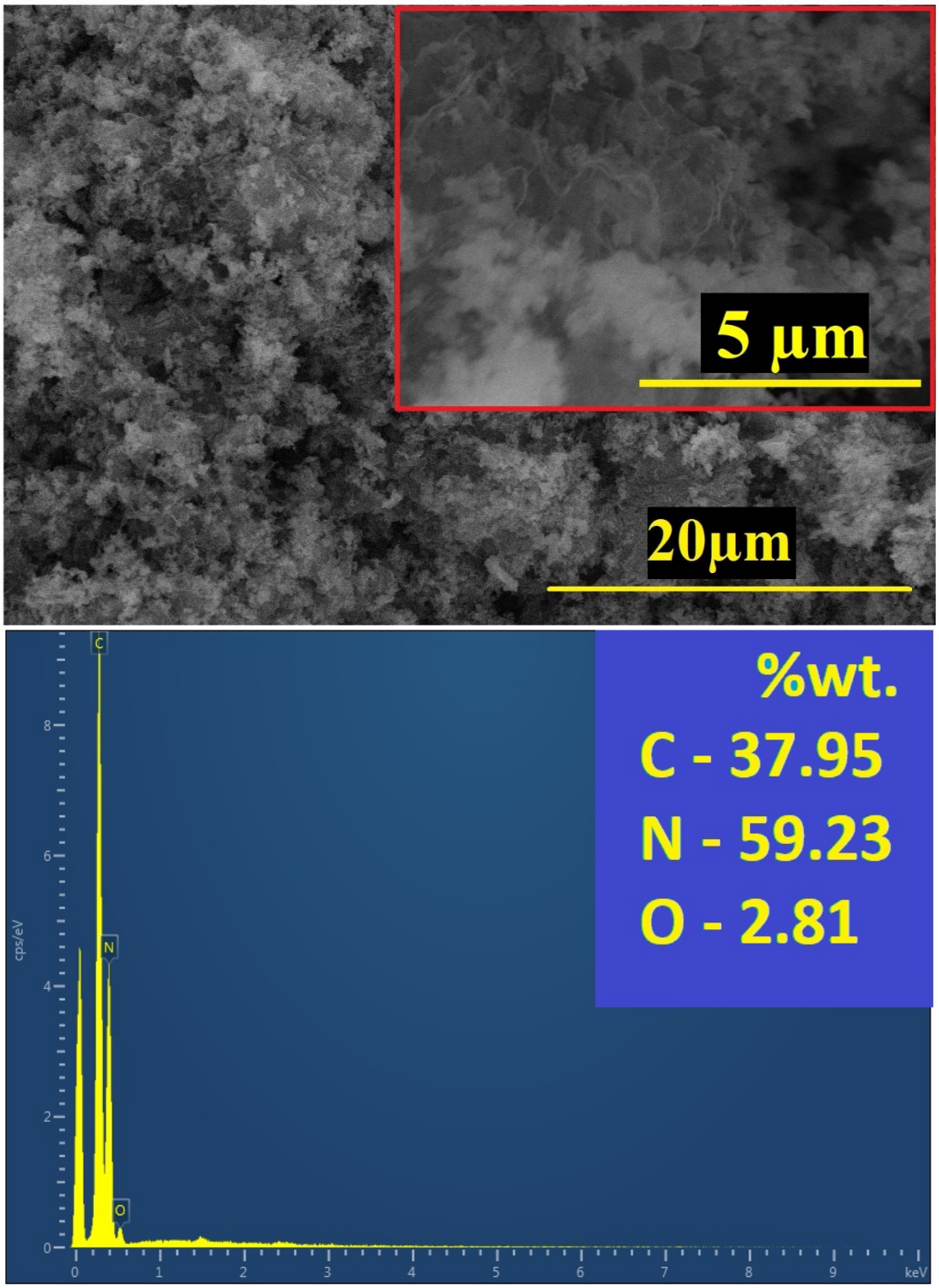


Figure S2. SEM images (a) and EDS (b) for Urea-550 sample.

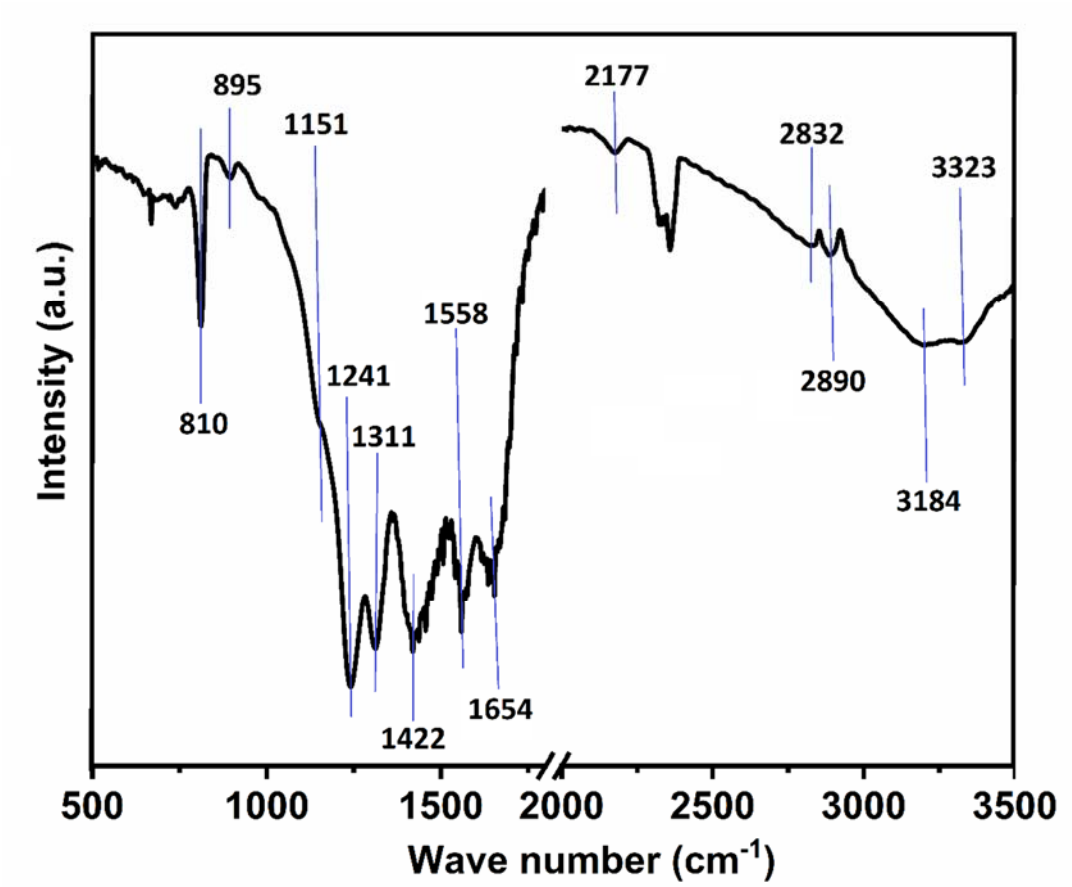
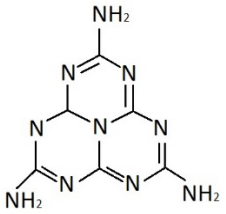
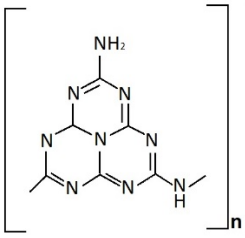


Figure S3. FTIR spectrum of Urea-550 sample.

Table S1.

Main absorption bands in the FTIR spectra of melem, melon and Urea-550.

Absorption bands position, cm^{-1}			**Absorption bands type**
Melem 	**Melon** 	**Urea-550**	
802	805	810	Condensed triazole rings
976	890	895	C-C and C-N bonds
1088, 1155	1206	1151	
1255	1236	1241	
1323	1320	1311	
1475	1410, 1465	1422	Condensed triazole rings
1560		1558	Cyameluric ring
-	1580	1605	Condensed triazole rings
-	1640	1654	
2136,2282	-	2177	
2494, 2570	-	-	
2773	-	2832, 2890	
3103	3085	-	Amide (–NH–)
-	3165, 3250	3184	
3336	-	3323	

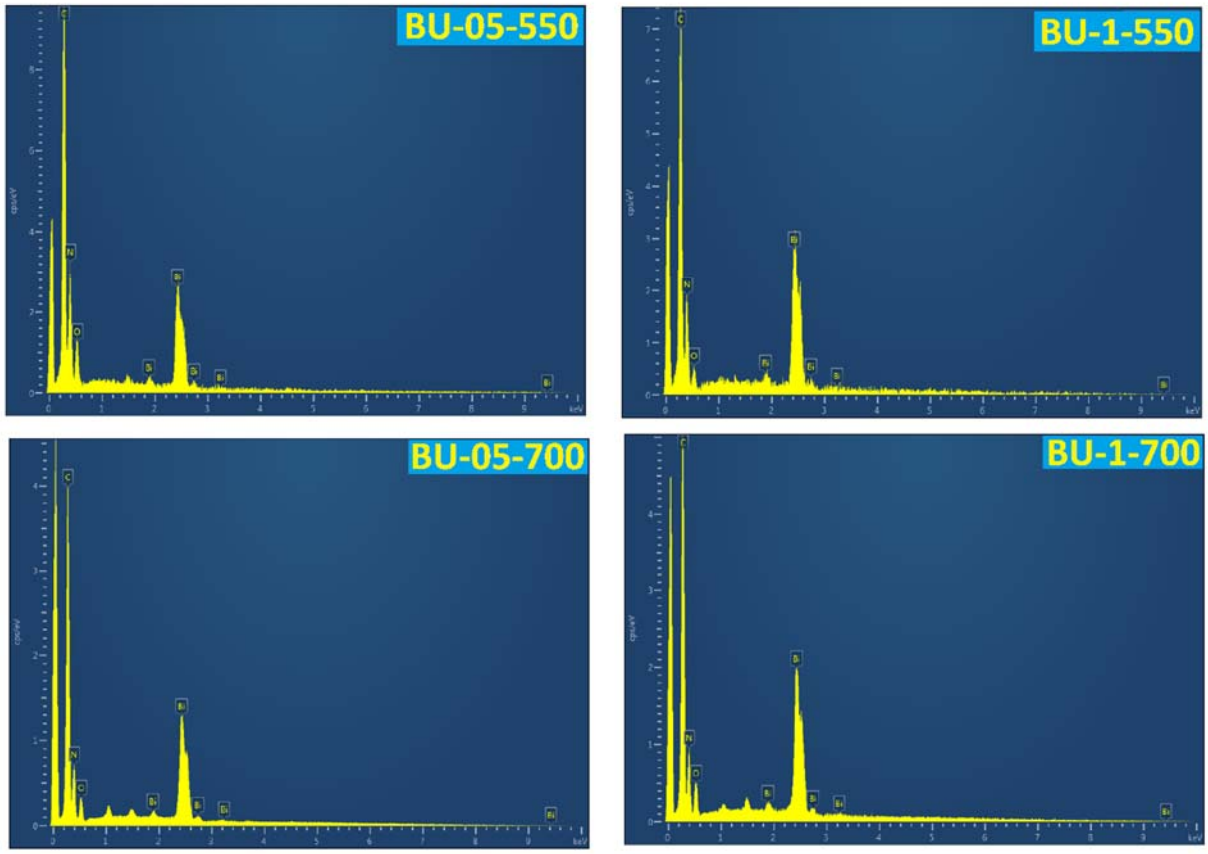


Figure S4. Results EDS for BU composites.

Table S2.

Element content and C: N ratio for BU according to EDS.

Sample	Found,% wt.				C:N ratio
	C	N	O	Bi	
BU-05-550	30.80	26.59	6.22	36.39	1.35
BU-05-700	36.26	16.24	3.90	43.60	2.61
BU-1-550	30.37	19.34	2.81	47.48	1.83
BU-1-700	31.21	12.93	3.73	52.12	2.81

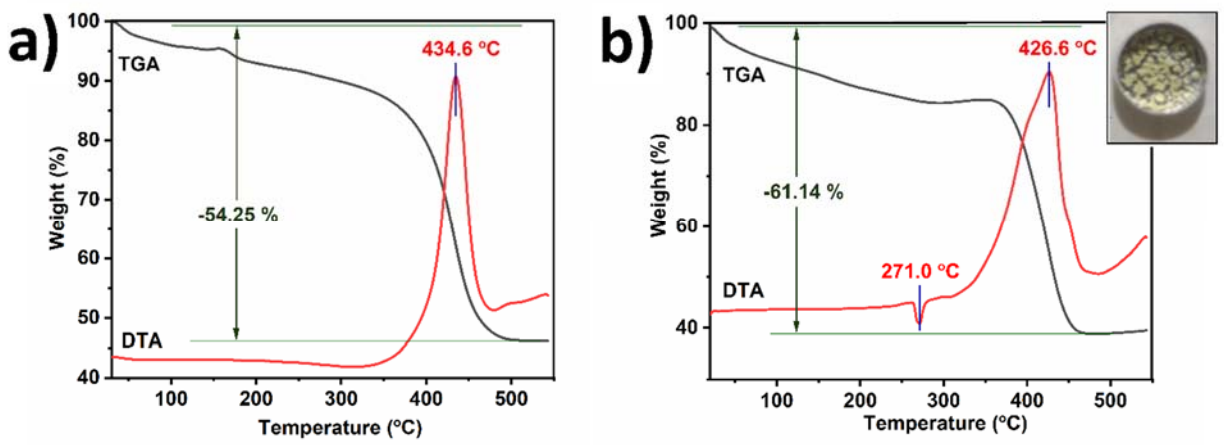


Figure S5. DG-DTA results for (a) BU-1-550 and (b) BU-05-700 (Insert: Bi_2O_3 obtained after DG-DTA).

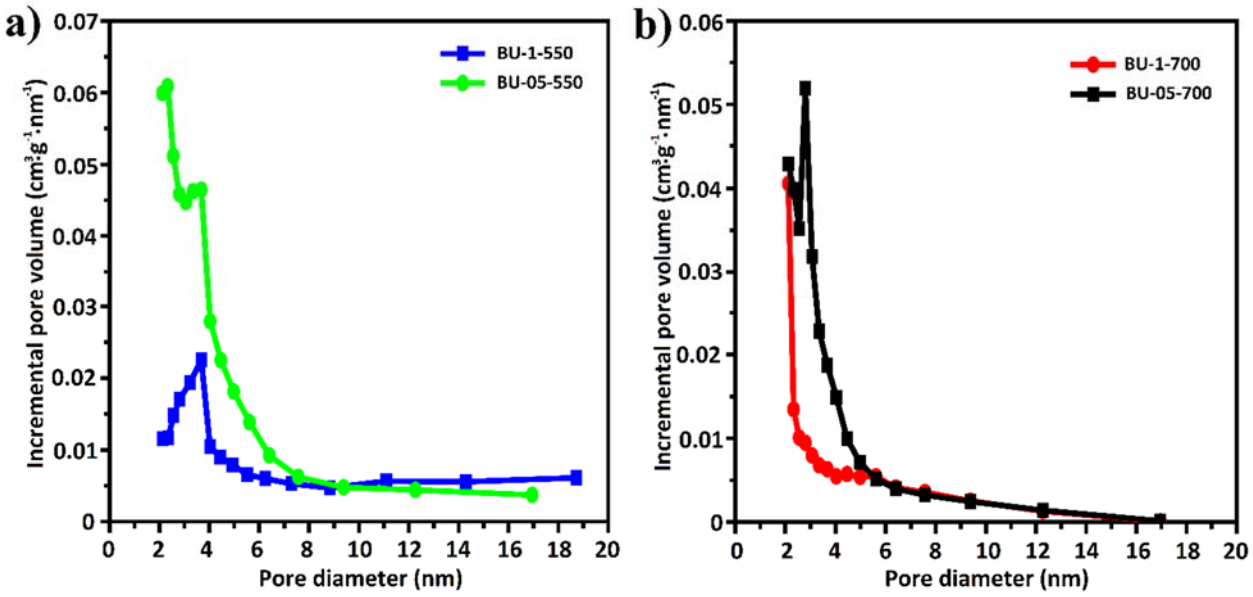


Figure S6. Barrett–Joyner–Halenda (BJH) pore size distribution curves of BU composites.

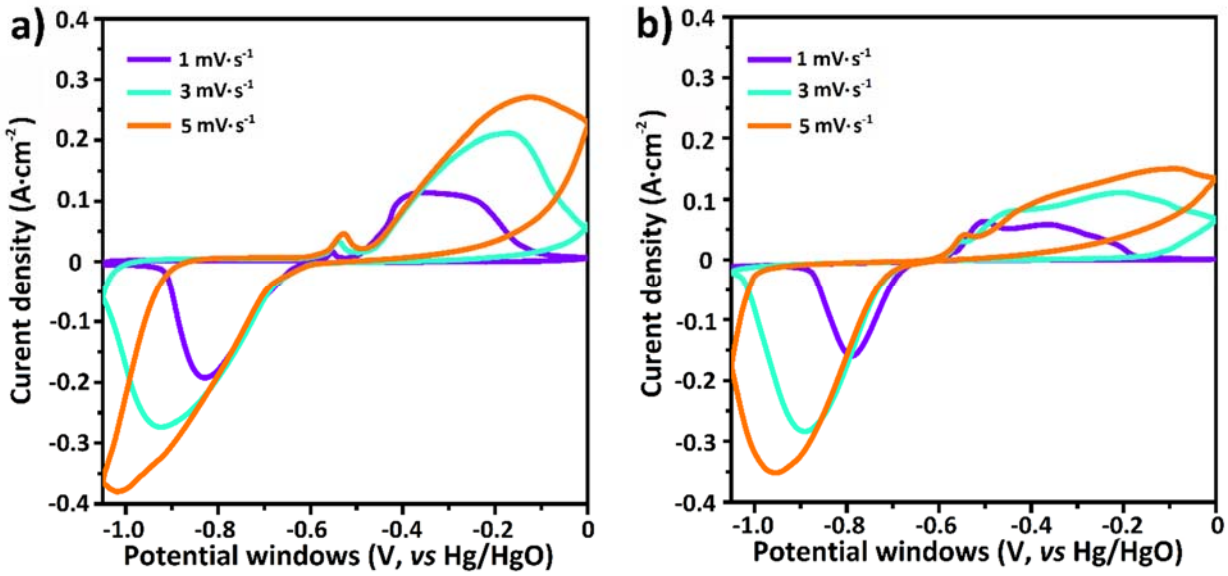


Figure S7. Cyclic voltammograms for (a) BU(05-700)-C/NF and (b) BU(1-550)-C/NF electrodes at different scan rates.

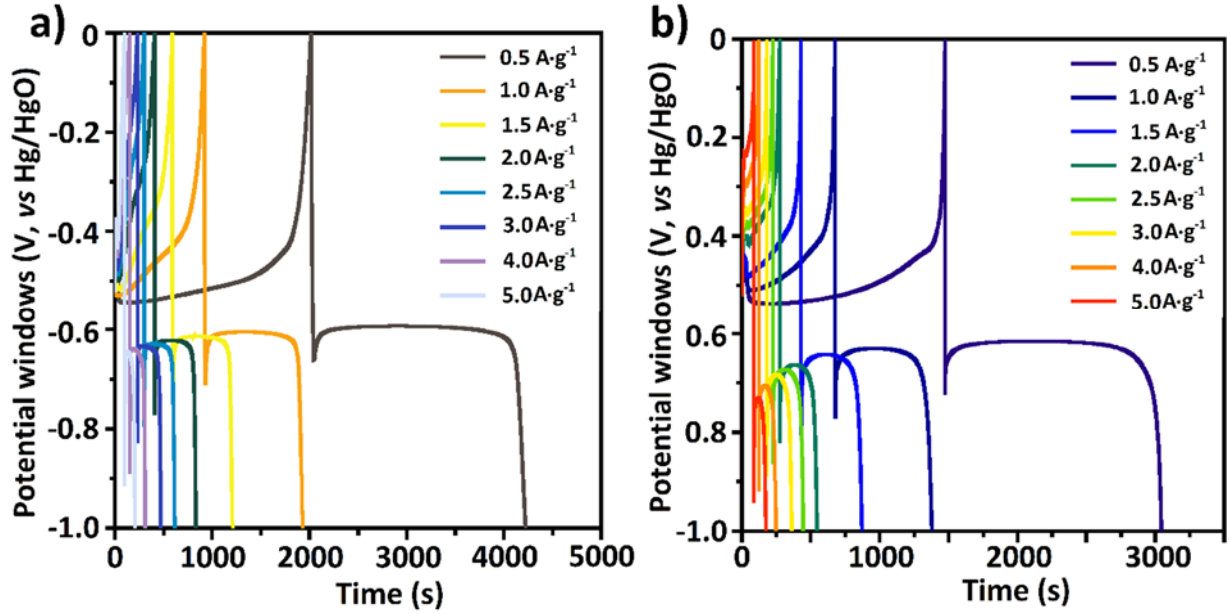


Figure S8. The galvanostatic charge−discharge curves for (a) BU(05-700)-C/NF and (b) BU(1-550)-C/NF electrodes at different current densities.

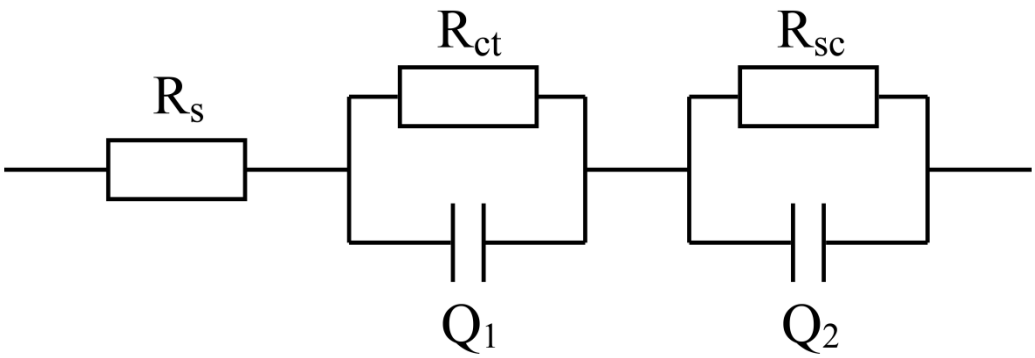


Figure S9. The equivalent scheme for EIS measurement: R_s – solution resistance, R_{sc} – specific space-charge resistance, R_{ct} – specific charge transfer resistance, Q_1 and $Q_2$are the constant phase elements (CPE) for the electrolyte/electrode interface and electrode surface, respectively.

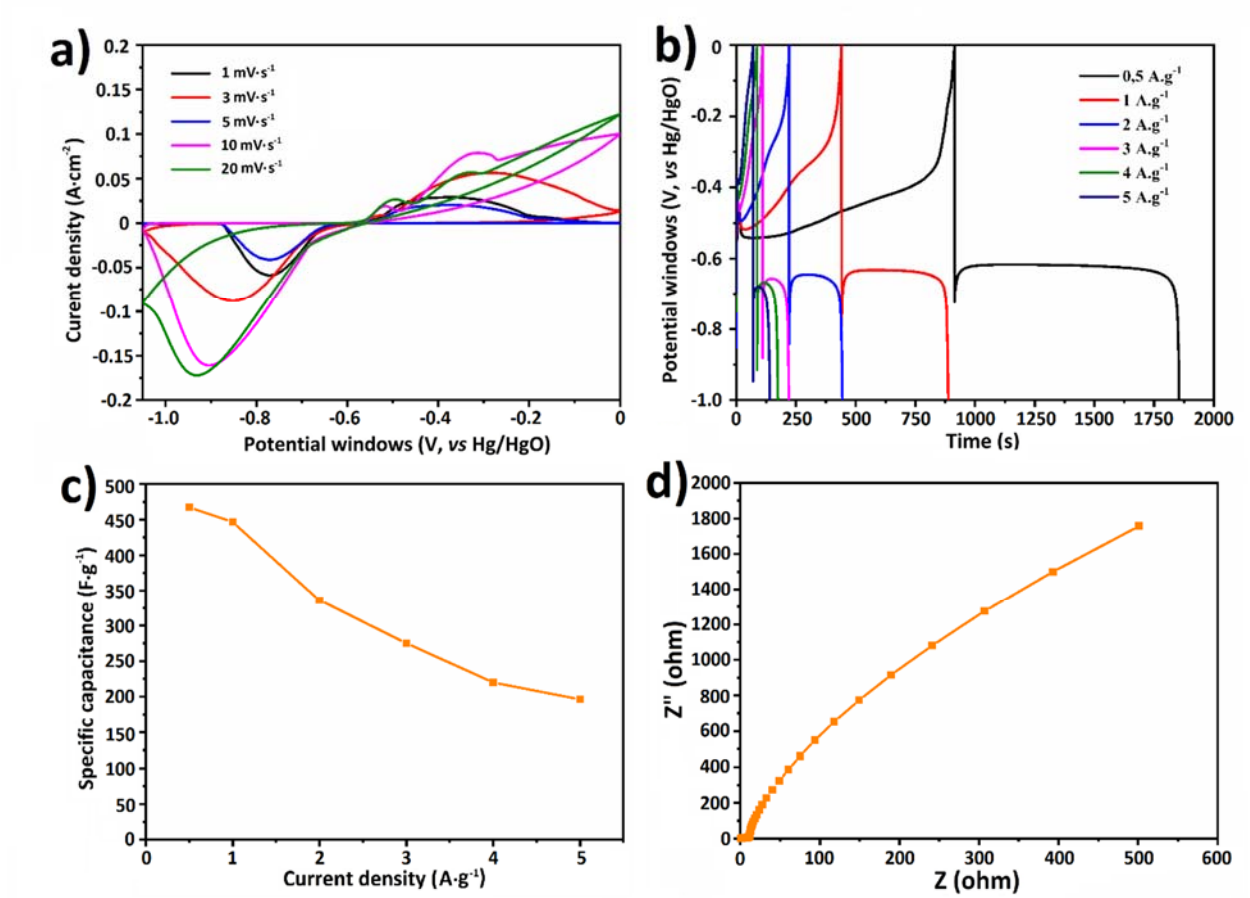


Figure S10. Electrochemical tests for Bi-700-C/NF* electrode: (a) CV curves at different scan rates; (b) galvanostatic charge−discharge curves at different current densities; (c) specific capacitances of the electrode at different current densities; (d) result AC impedance spectroscopy.

*The Bi-700-C/NF electrode was fabricated by coating strips of nickel foam with active paste, which consists of 85 % wt. electroactive material (prepared from thermally decomposed pure Bi(cit) at 700 ° C in an Ar atmosphere) with a mixture of 10 % wt. SP carbon and 5 % wt. PTFE. The resulting electrode was dried in vacuum at 60 °C for 24 hours.

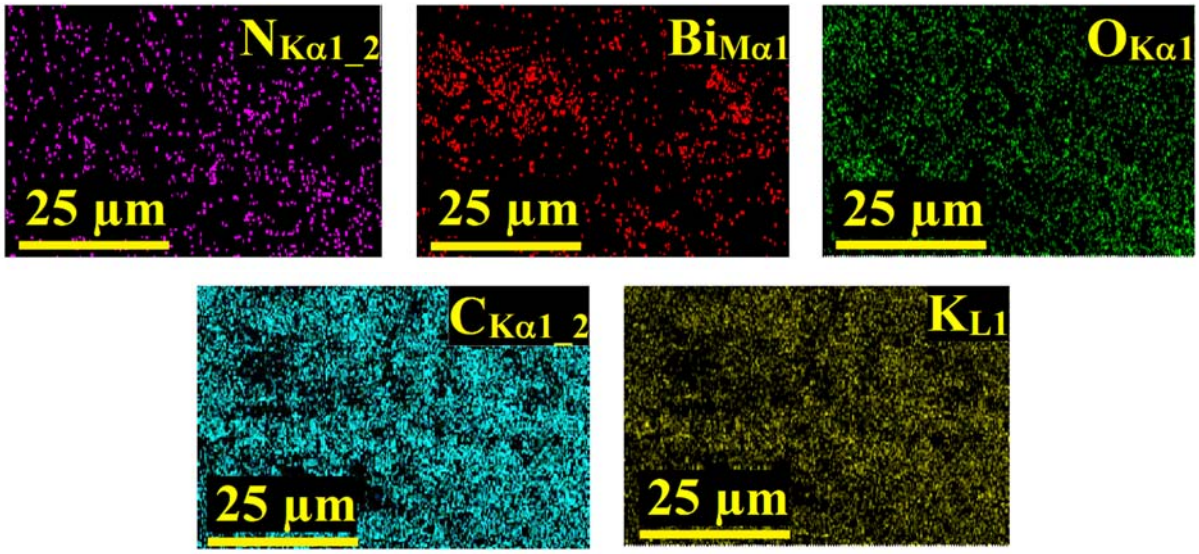


Figure S11. Elemental mapping for BU(1-700)-C/NF electrode after GCD the process.

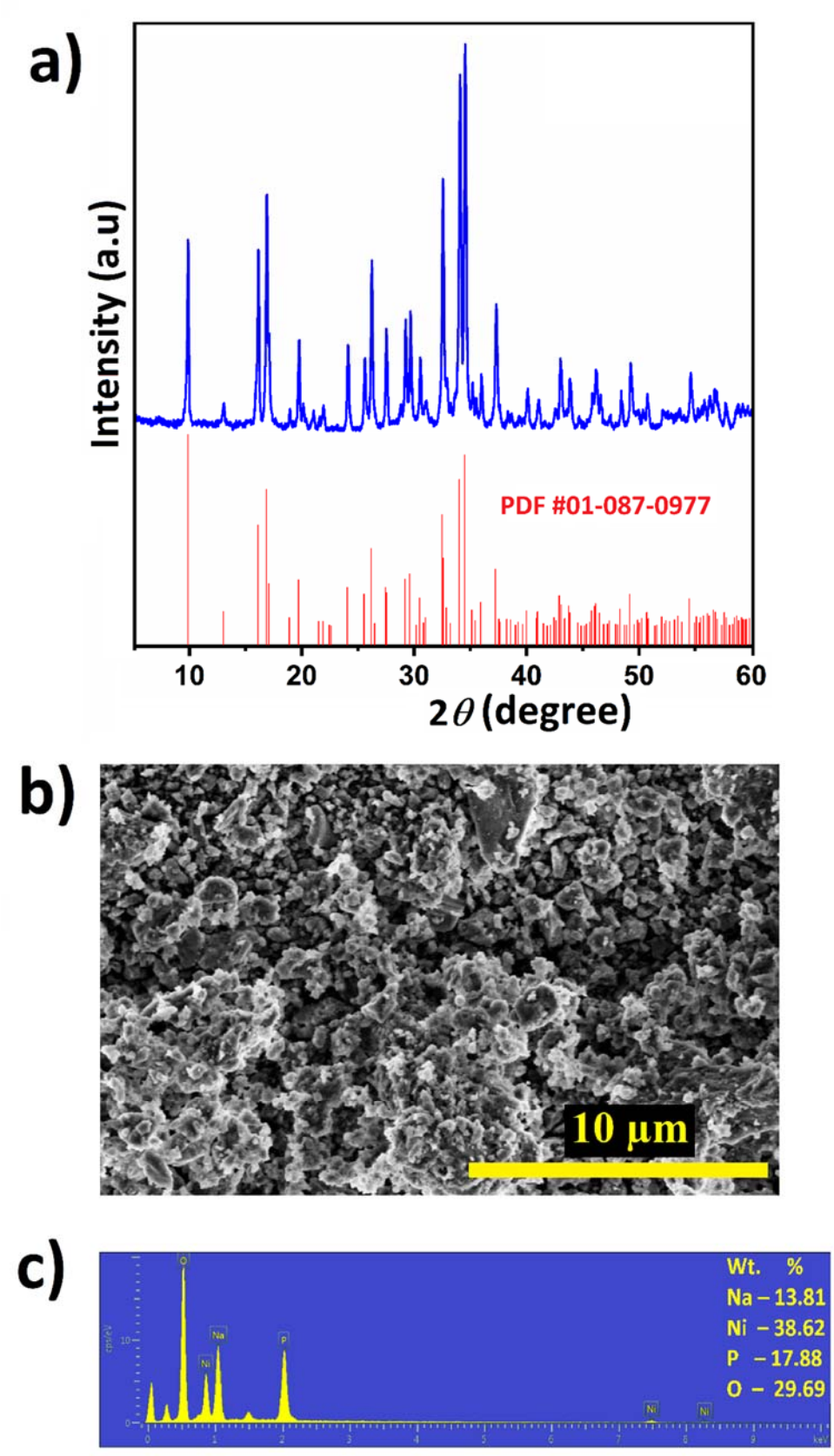


Figure S12. Characterization of the obtained nanoparticles $Na_4Ni_3P_4O_{15}$: (a) XRD result (in comparison with PDF2 #01-087-0977 for $Na_4Ni_3(PO_4)_2P_2O_7$); (b) SEM image; (c) result EDS.

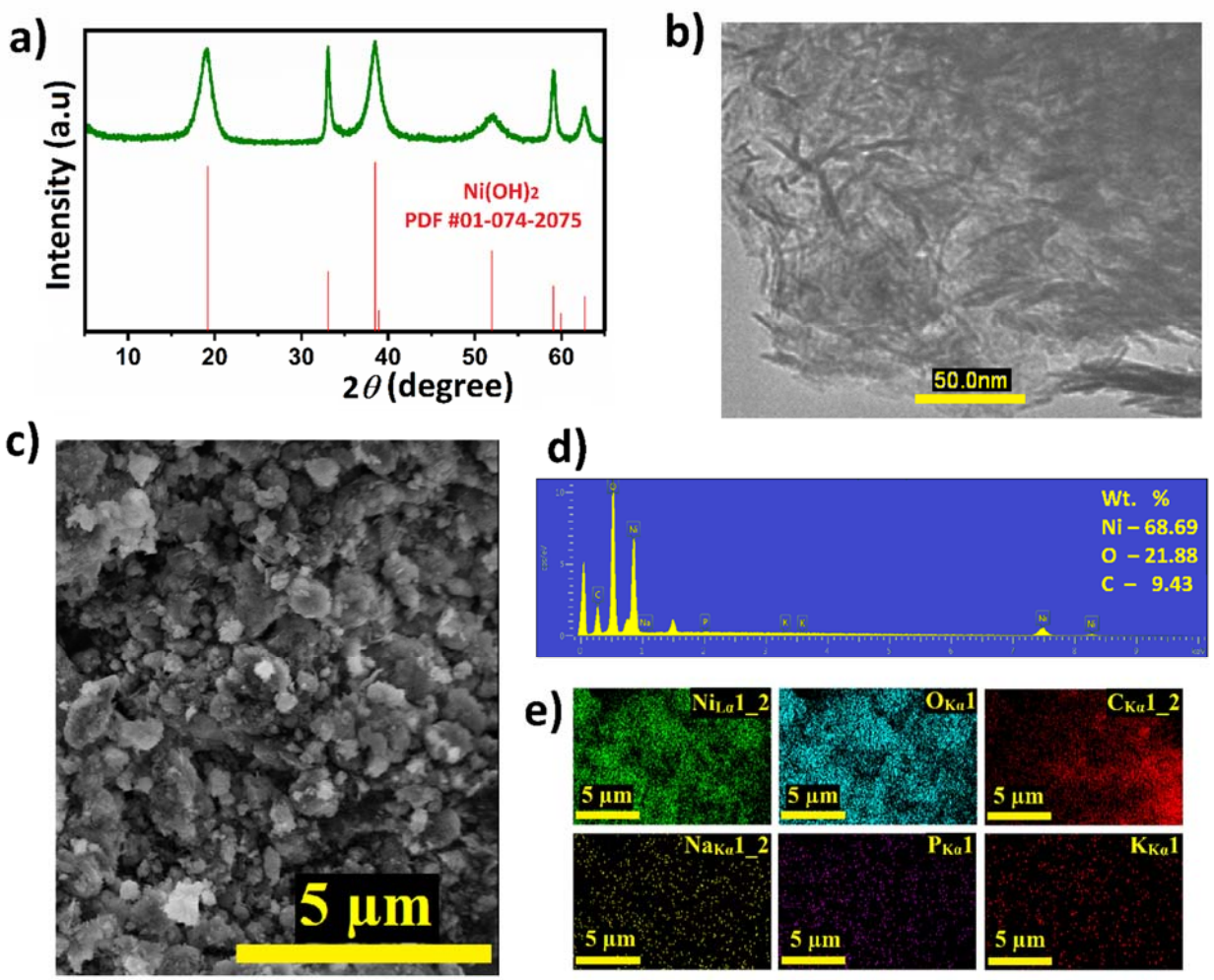


Figure S13. Study of the NiLH-C/NF electrode after *in situ* conversion of phosphate to 2D-nanosheets $Ni(OH)_2$ (in a 6 M KOH solution): (a) XRD data; (b) TEM image (crumbs of electrode material were separated from surface of NF current collector; used transmission electron microscopy by JEOL JSM 2010F, recorded at 200 kV); (c) SEM image for NiLH-C/NF electrode; (d) result EDS; (e) elemental mapping for NiLH-C/NF electrode.

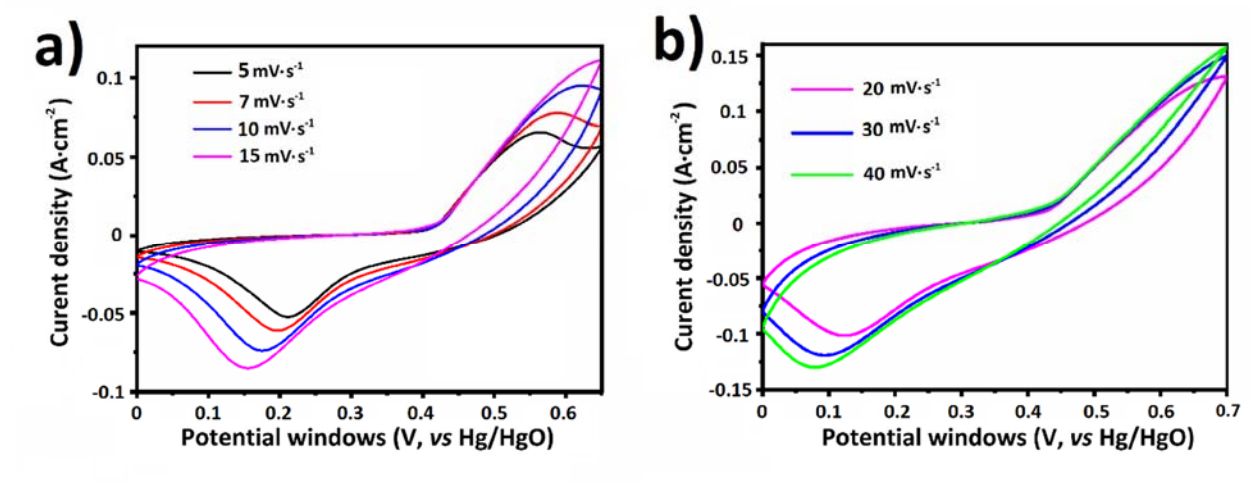


Figure S14. CV curves at different scan rates for NiLH-C/NF electrode: (a) scanning rate from 5 to 15 $mV \cdot s^{-1}$; (b) scanning rate from 20 to 40 $mV \cdot s^{-1}$.

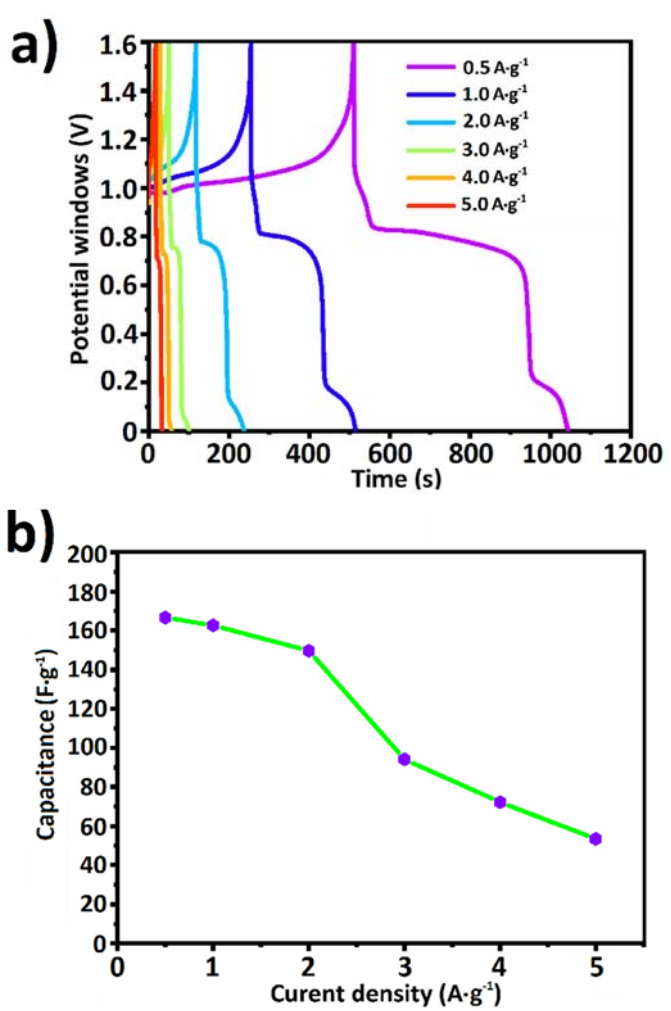


Fig. S15. Electrochemical tests for BU-C/NF//NiLH-C/NF device: (a) galvanostatic charge−discharge curves at different current densities; (b) specific capacitances of the supercapacitor at different current densities.