Electronic Supplementary Material (ESI) for Environmental Science: Water Research & Technology.

The Feasibility of Hollowed Echinus-like $NiCo_2O_4$ Nanocrystal for Hybrid Capacitive Deionization

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Calculation

The water recovery (WR, %), as the following equation:

$$V_d = \int_{\Delta V_d} Q dt \quad (1)$$

$$V_c = \int_{\Delta V_c} Q dt \quad (2)$$

$$WR = \frac{V_d}{V_d + V_c} \quad (3)$$

Where Q is the volumetric through the device, V_d is volume of solution after adsorption, V_c is the volume of initial solution, ΔV_d is the time to collect fresh water, ΔV_c is the time to collect concentrated water.

For volumetric energy consumption per cell (E_v, Wh/m^3), It is calculated according the following equation:

$$E_{in} = \int_{\Delta t_{clcle}} IV dt \qquad where \quad IV > 0 \quad (4)$$

$$E_{out} = \int_{\Delta t_{clcle}} IV dt \qquad where \quad IV < 0 \quad (5)$$

$$E_v = \frac{E_{in} - \eta E_{out}}{V_d} \quad (6)$$

where IV is the current-voltage product in the CDI unit (W), Δt_{clcle} is the total dynamic-steady state (DSS) cycle time (min), E_{in} is the total energy input during the DSS cycle (J), E_{out} is the total recoverable energy from the cell over the DSS cycle (J), η is the part of E_{out}, which means that the solution has been recovered. If energy has been fully recovered, η can be approximately equal to 1.

Terminology productivity is calculated as the follow equation:

$$P = \frac{V_d}{n \cdot A \cdot \Delta t_{clcle}}$$

(7)

Where P is the productivity in L/h/m^2, n is the number of unit (electrode pairs) in CDI, and A is the electrode area (cm^2).

Table S1 Comparison of the desalination performance among various electrodes

Electrode materials	Potential (V)	electrolyte concentration (mg/L)	ASRR (mg/g/min)	WR (%)	Productivity ($L/h/m^2$)	Concentration reduction (mM)	salt removal capacity (mg/g)	Ref.
G@MC/ G@MC	1.5	500	\	21	300	2	24.3	7
CNT/G / CNT/G	2.0	780	\	28	\	12.88	26.4	10
$Na_2FeP_2O_7$/ AC	1.2	585	4.86	66	400	\	32.6	15
$Na_{1.1}V_3O_{7.9}$ @rGO/ Ag@rGO	1.4	500	2.772	60	793	3.77	60.3	16
graphene@ $Na_4Ti_9O_{20}$/ AC	1.4	264	\	\	\	0.85	41.8	17
$NiCo_2O_4$/ AC	1.4	529	5.611	56	416	1.59	44.4	This work

Fig. S1 elemental mapping of $NiCo_2O_4$ with Ni, Co and O.

Fig. S2 (a) GCD curves of $NiCo_2O_4$, (b) specific capacitance of $NiCo_2O_4$ at various current densities.

Fig. S3 (a) and (b) conductivity transient of AC ‖ $NiCo_2O_4$ HCDI device in 500 and 2000 μS/cm of NaCl solution at different cell voltage, respectively, (c) the effect of voltage on CDI Ragone Kim-Yoon-Plot in NaCl solution, (d) the PH variation.

Fig. S4 (a) XRD patterns of $NiCo_2O_4$, after sodium intercalation, and after sodium deintercalation. (b) FT-IR spectrum of AC.

Fig. S5 (a) conductivity transient at the flow rate of 41 mL/min, (b) the salt removal capacity of AC ‖ $NiCo_2O_4$ HCDI with respect to time.

Fig. S6 (a) The conductivity transient of AC ‖ $NiCo_2O_4$ HCDI in NaCl, LiCl, KCl and $MgCl_2$ solution with initial conductivity of 1000 μS/cm, (b) the concentration variation of Na^+, K^+, Li^+ and Mg^{2+} before and after adsorption, (c) the conductivity transient of AC ‖Co_3O_4, AC ‖ NiO and AC ‖ $NiCo_2O_4$ in NaCl solution, respectively, (d) the salt removal capacity.

Fig. S1

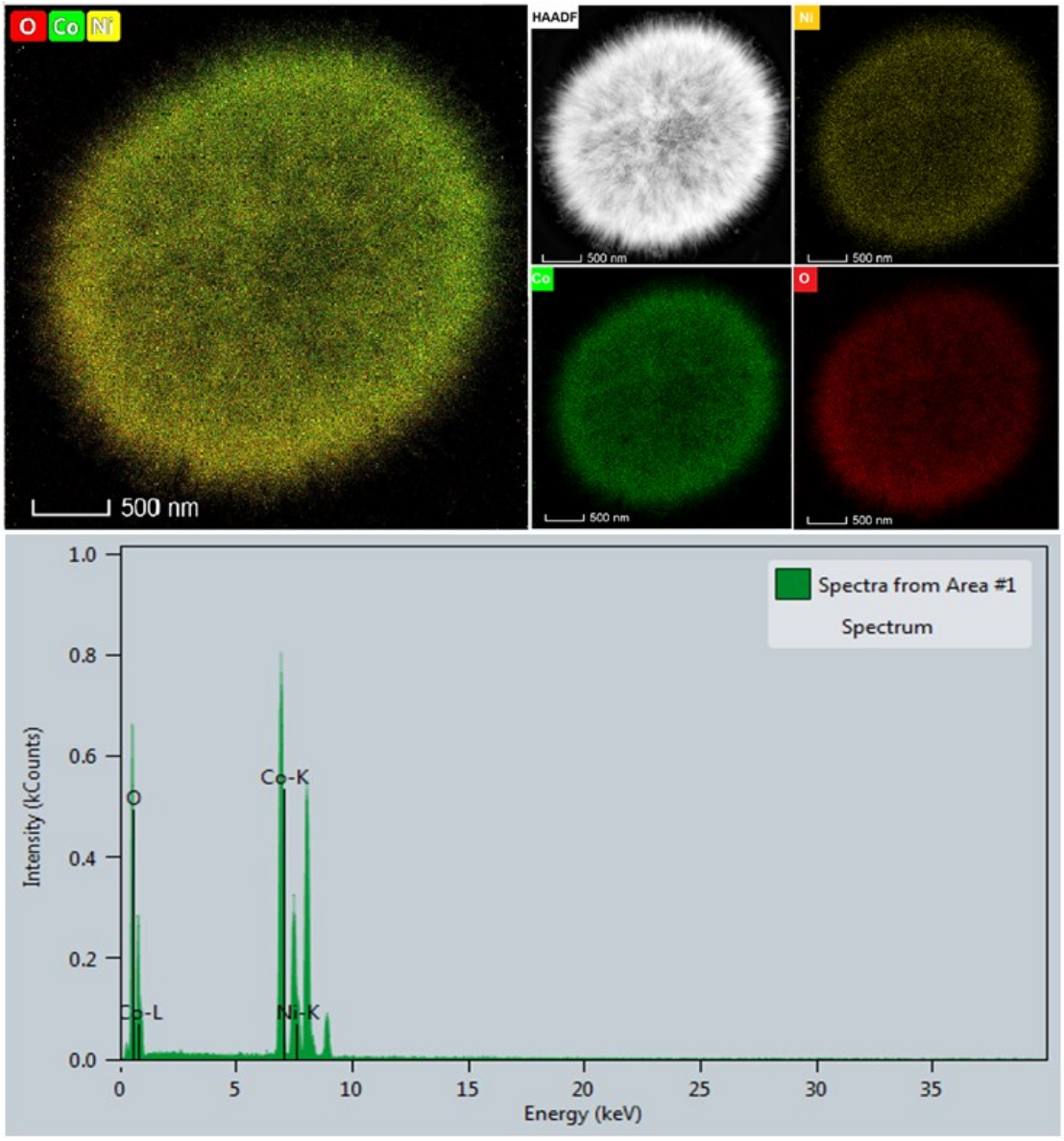

O
Co
Ni
500 nm
HAADF
500 nm
Ni
500 nm
Co
500 nm
O
500 nm
Spectra from Area #1
Spectrum
Intensity (kCounts)
1.0
0.8
0.6
0.4
0.2
0.0
O
Co-K
Co-L
Ni-K
0
5
10
15
20
25
30
35
Energy (keV)

Fig. S2

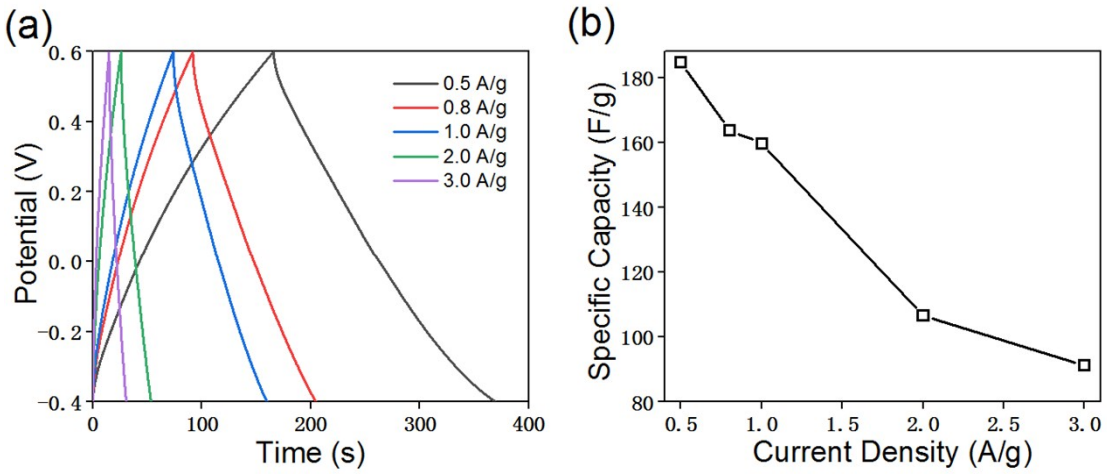

(a)
Potential (V)
Time (s)
0.5 A/g
0.8 A/g
1.0 A/g
2.0 A/g
3.0 A/g
(b)
Specific Capacity (F/g)
Current Density (A/g)

Fig. S3

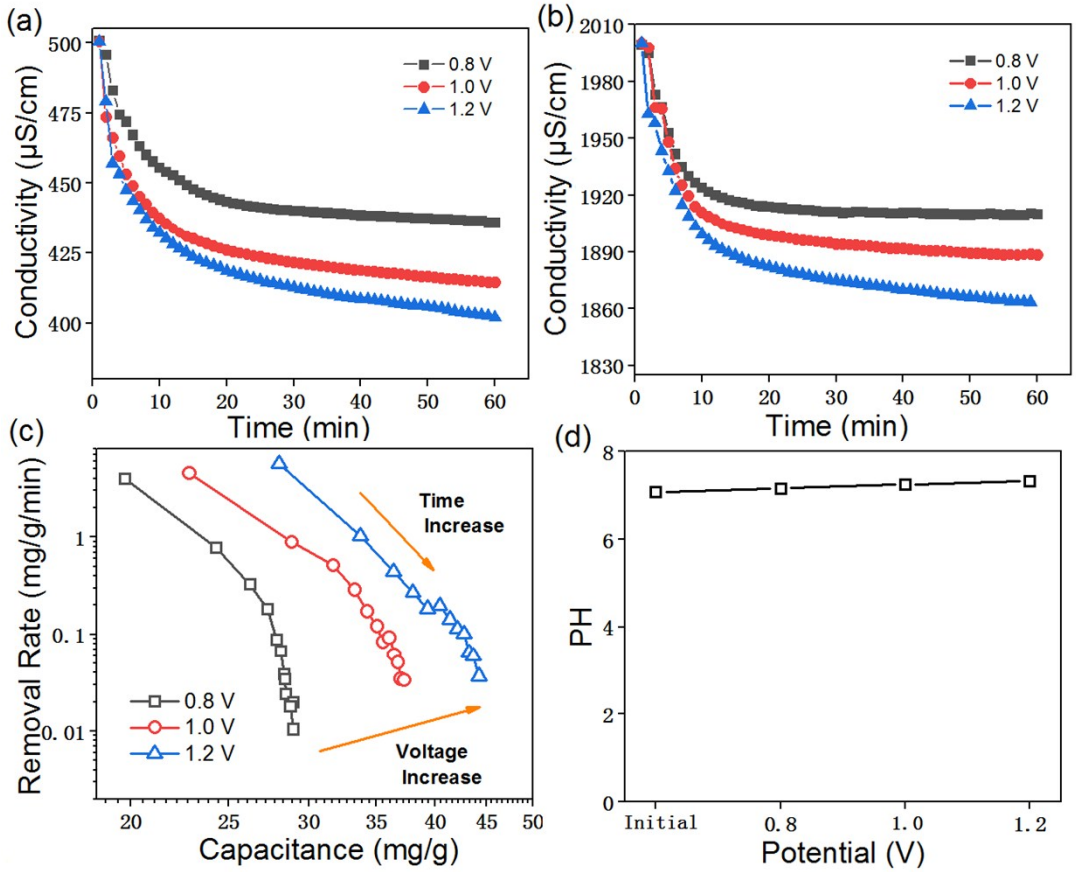

(a)
Conductivity (μS/cm)
Time (min)
0.8 V
1.0 V
1.2 V
(b)
Conductivity (μS/cm)
Time (min)
0.8 V
1.0 V
1.2 V
(c)
Removal Rate (mg/g/min)
Capacitance (mg/g)
Time Increase
Voltage Increase
0.8 V
1.0 V
1.2 V
(d)
PH
Potential (V)
Initial
0.8
1.0
1.2

Fig. S4

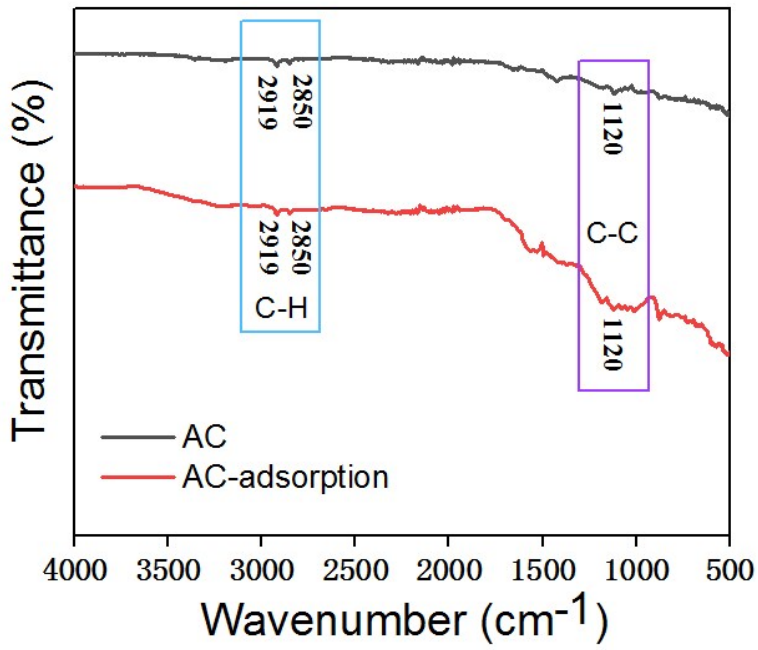

Transmittance (%)
2919
2850
2919
2850
C-H
1120
C-C
1120
AC
AC-adsorption
4000
3500
3000
2500
2000
1500
1000
500
Wavenumber (cm-1)

Fig. S5

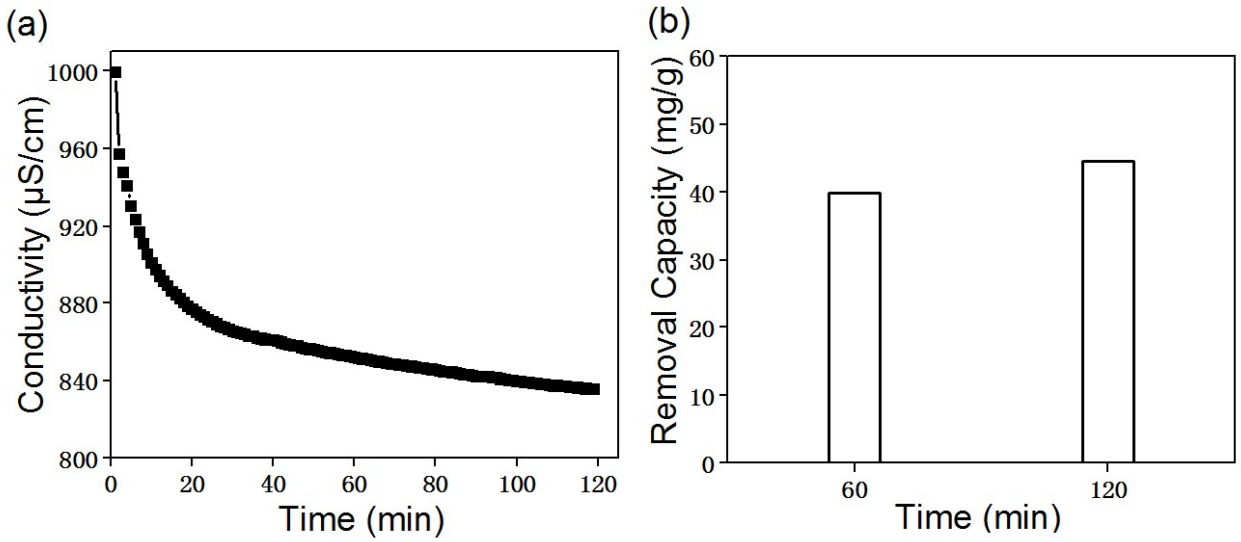
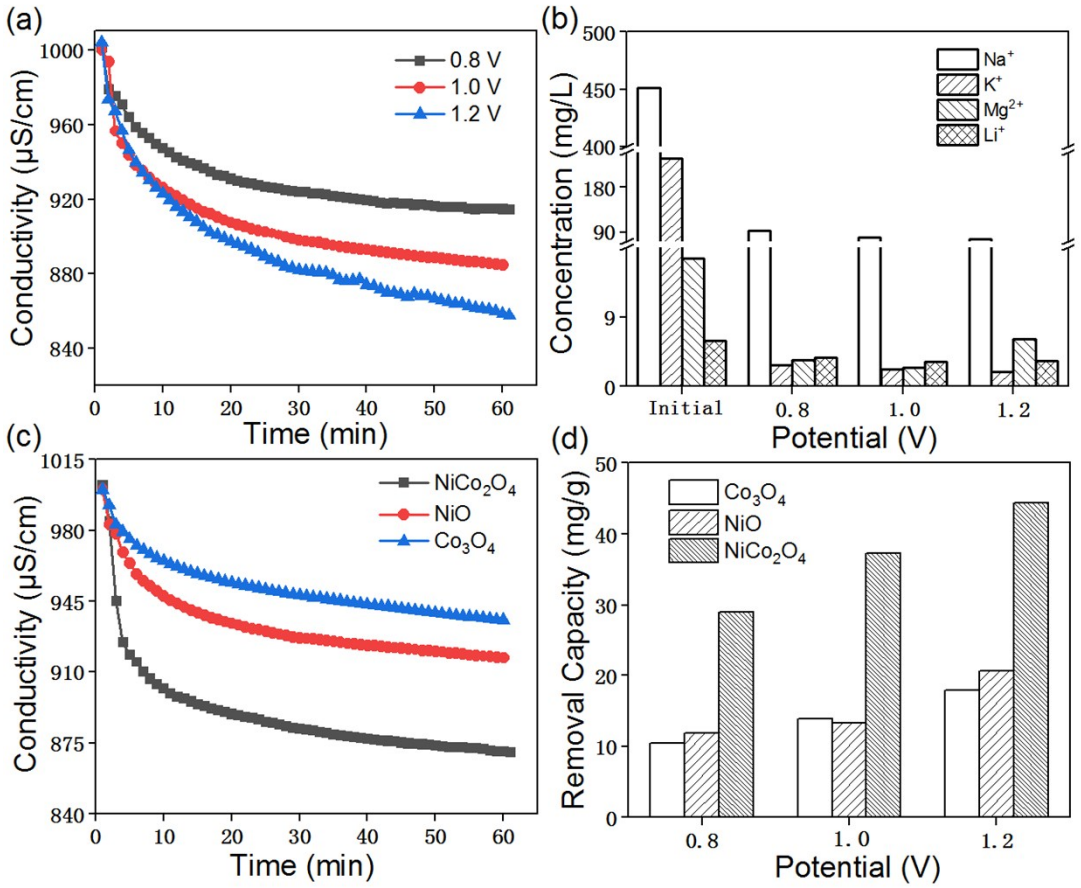

(a)
Conductivity (μS/cm)
1000
960
920
880
840
800
0
20
40
60
80
100
120
Time (min)
(b)
Removal Capacity (mg/g)
60
50
40
30
20
10
0
60
120
Time (min)

Fig. S6


(a)
Conductivity (μS/cm)
Time (min)
0.8 V
1.0 V
1.2 V
(b)
Concentration (mg/L)
Potential (V)
Initial
Na+
K+
Mg2+
Li+
(c)
Conductivity (μS/cm)
Time (min)
NiCo2O4
NiO
Co3O4
(d)
Removal Capacity (mg/g)
Potential (V)
Co3O4
NiO
NiCo2O4