Supporting Information

Construction of a Hierarchical $NiCo_2S_4$@PPy Core-Shell Heterostructure Nanotube Array on Ni Foam for a High-Performance Asymmetric Supercapacitor

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Calculation formulas:

(1) Single electrode

The area specific capacitances of the samples are calculated from the CV curves using the following formula [1]:

$$Cs = \frac{1}{sv(V_a - V_c)} \int_{V_a}^{V_c} I(V)dV \quad \text{(Formula S1)}$$

Where the Cs (F/cm^2) is the area specific capacitance, I is the response current (A), s is the area of activate materials loaded on the Ni foam, v is the rate (mV/s) and Vc and Va are the high and low potential limits of the CV tests.

The area and mass specific capacitances of the samples are calculated from the GCD curves using the following formula [2]:

$$Cs = \frac{I \times \Delta t}{s \times \Delta V} \quad \text{(Formula S2)}$$

$$Cm = \frac{I \times \Delta t}{m \times \Delta V} \quad \text{(Formula S3)}$$

Where the Cs (F/cm^2) is the area specific capacitance, the Cm (F/g) is the mass specific capacitance, I is the response current (A), s is the area of activate materials loaded on the Ni foam, m is the mass of activate materials loaded on the Ni foam, Δt is the discharge time, ΔV is potential window of the discharge process.

(2) Supercapacitor device

The area and mass specific capacitances of the supercapacitor device calculated from the GCD curves is similar to those of single electrode.

The mass loading of activated carbon was determined by balancing the charges stored in each electrode. Its specific mass was calculated by the following formula [3]:

$$C_{s+}\Delta V_{+}S = C_{m-}\Delta V_{-} m_{-} \qquad \text{(Formula S4)}$$

Where m is the mass loading, C_{s+} and C_{m-} represent the specific capacitance of positive electrode (F/cm^2) and negative electrode (F/g) respectively. ΔV is the potential window of positive (+) and negative (-) electrode. S is the area of Ni foam supported $NiCo_2S_4$@PPy-50. m_- is the mass of negative electrode.

The energy density (E) and power density (P) are obtained according to the following formulas [4]:

$$E = \frac{1}{2}C\Delta V^2 \qquad \text{(Formula S5)}$$

$$P = \frac{E}{\Delta t} \qquad \text{(Formula S6)}$$

Where E (Wh/kg) is the energy density, C (F/g) is the mass specific capacitance, ΔV (V) is the voltage window, P (W/kg) refers to the power density and Δt (s)is the discharge time.

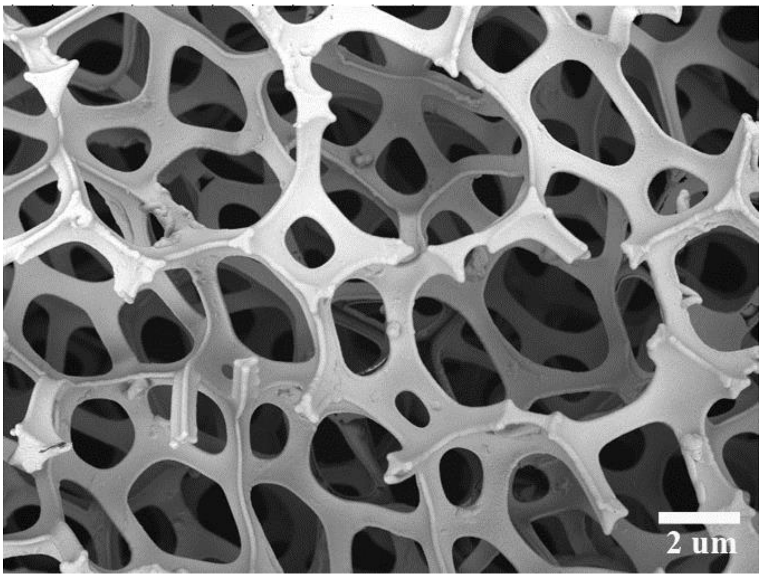

Figure S1 SEM image of Ni foam.

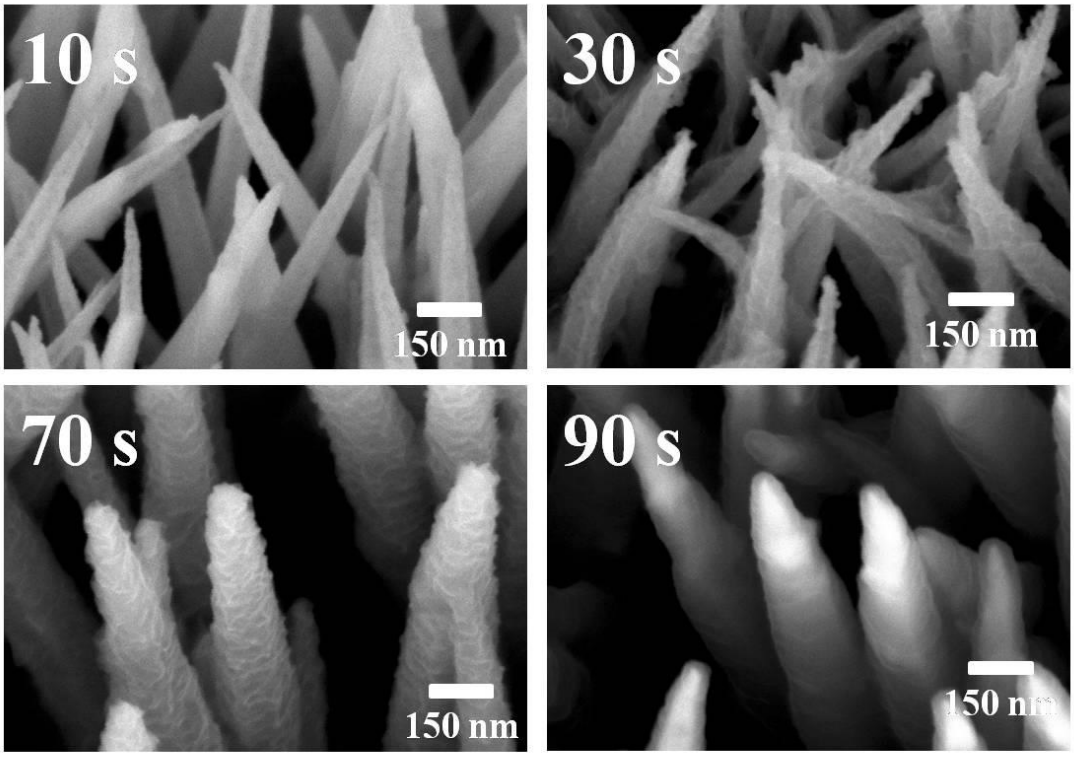

Figure S2 SEM images of $NiCo_2S_4$@PPy NTA/NF by using different electrodeposition time.

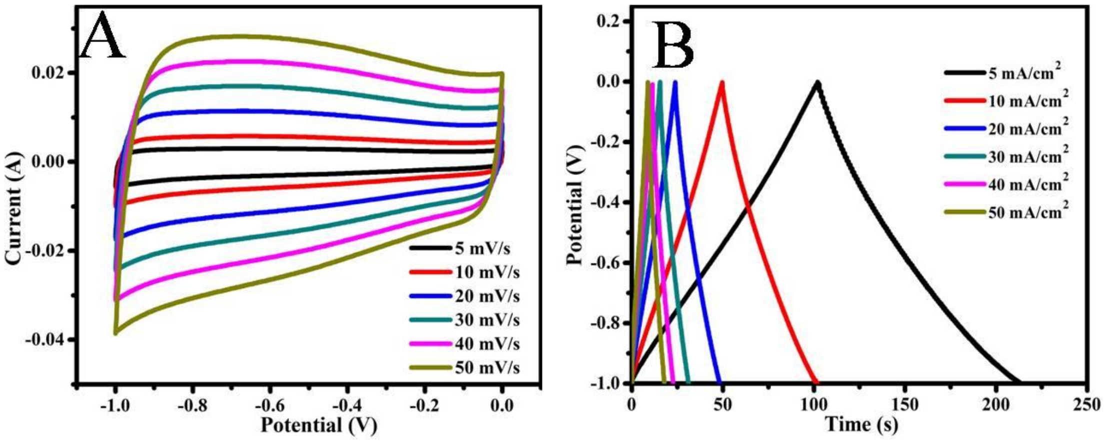

Figure S3 (A) CV curves of the AC at different scan rates; (B) GCD curves of the AC at different current densities.

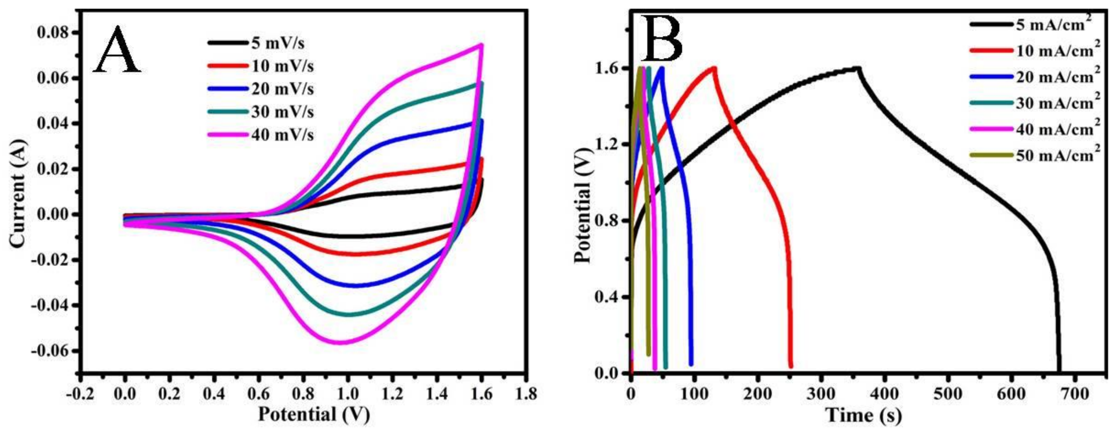

Figure S4 (A) CV curves of $NiCo_2S_4$//AC at different scan rates; (B) GCD curves of $NiCo_2S_4$//AC at different current densities.

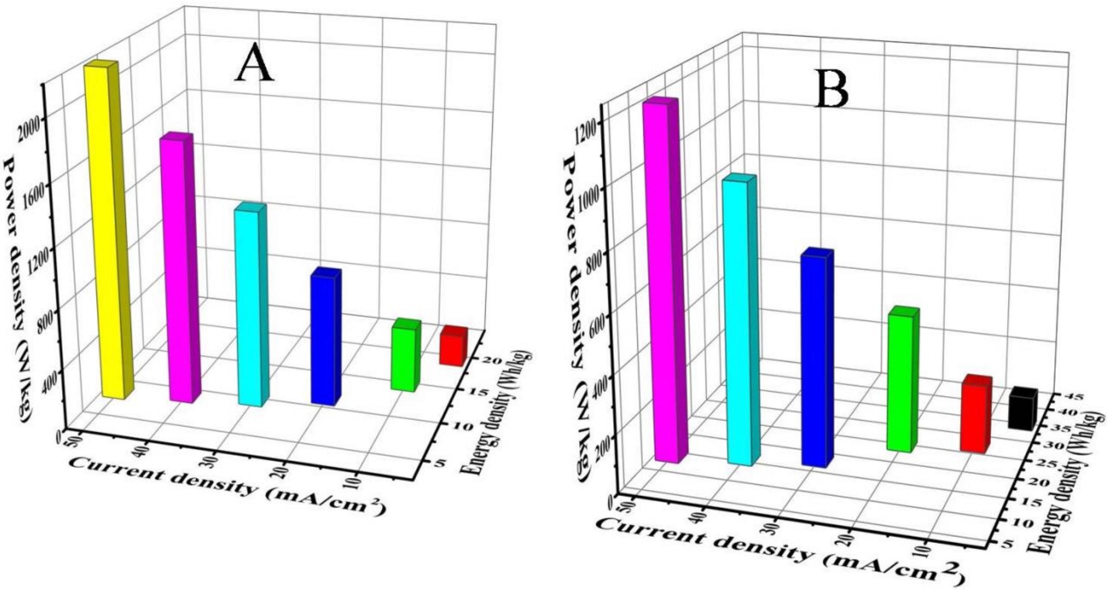

Figure S5 (A) the energy density and power density of $NiCo_2S_4$//AC at different current densities; (B) the energy density and power density of $NiCo_2S_4$@PPy-50//AC at different current densities.

Table S1 Comparison of synthesis method, morphology and electrochemical performance of different electrode materials

Electrode material	Method	Morphology	Specific capacitance	Capacitance retention	Ref.
Carbon@ $NiCo_2S_4$	hydrothermal	nanorods	1455 F/g at 1 A/g	83% after 2000 cycles at 20 A/g	5
$NiCo_2S_4$@ $NiCo_xS_y$	hydrothermal and electrodeposition	core-shell nanotube arrays	3.9 F/cm^2 at 1 mA/cm^2	77% after 1500 cycles at 10 mA/cm^2	6
$NiCo_2S_4$@CoS_x	hydrothermal	core-shell nanotube arrays	4.74 F/cm^2 at 5 mA/cm^2	76.1% after 1500 cycles at 50 mA/cm^2	7
$NiCo_2S_4$/CFC	solvothermal	Burl-like	0.83 F/cm^2 at 25 mA/cm^2	75.9% after 5000 cycles at 20 mA/cm^2	8
CoS @ $NiCo_2S_4$	ion exchange process	core-shell nanoarrays	7.62 F/cm^2 at 5 mA/cm^2	71.7% after 3000 cycles at 10 mA/cm^2	9
$NiCo_2S_4$ @MnO_2	hydrothermal	core-shell nanotubes	1337.8 F/g at 2 A/g	82% after 2000 cycles at 20 A/g	10
$CoNi_2S_4$	hydrothermal	mushroom-like	5.71 F/cm^2 at 20 mA/cm^2	80.91% after 3000 cycles at	11

				20 mA/cm^2	
$NiCo_2S_4$ /MWCNTs	solvothermal reaction	nanotubes	2080 F/g at 1 A/g	83% after 2000 cycles at 8 A/g	12
$NiCo_2S_4$@PPy	hydrothermal and electrodeposition	core-shell nanotube arrays	9.781 F/cm^2 (1364 F/g) at 5 mA/cm^2	72.19% after 3000 cycles at 50 mA/cm^2	This work

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