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Support Information

A facile synthesis of $Ni_{0.85}Se@Cu_{2-x}Se$ nanorods as high-performance supercapacitor electrode materials

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Contents:

1. Electrochemical Measurements

The electrochemical performance of the $Ni_{0.85}Se@Cu_{2-x}Se$ electrodes are tested by a three-electrode system with a 3 M KOH as electrolyte. The Hg/HgO and Pt electrode were utilized as reference electrode and counter electrode.[1, 2] The samples prepared by one-step route was dried at 60 °C under vacuum for 12 h and then was used directly as the working electrode. All the electrochemical measurements were performed on an electrochemical workstation (CHI 660E, Shanghai chenhua, China). The potential window ranges of cyclic voltammetry (CV) and galvanostatic charge-discharge curve (GCD) were set as 0-0.6 V and 0-0.45 V, respectively. The Electrochemical impedance spectroscopy (EIS) is performed in a frequency range from 0.01 Hz to100 kHz. The $Ni_{0.85}Se@Cu_{2-x}Se$ electrode is used as the positive electrode and the activated carbon (AC) is used as the negative electrode in the two-electrode test system.

2. Material Characterizations.

The phase characterization of the samples was analyzed by X-ray powder diffractometer (XRD, Japanese, Rigaku D/Max-3c) with a Cu Ka radiation (λ= 1.5418 Å), and the test voltage was 40 kV. The morphologies, chemical composition and microstructures of the as-obtained samples were characterized by field emission scanning electron microscope (FE-SEM, Hitachi S-4800, Japan), energy disperse X-ray spectroscopy (EDX attached to FE-SEM), X-ray photoelectron spectroscopy (XPS，AXIS SUPRA(Kratos), and transmission electron microscopy (TEM，FEI Tecnai G2F20).

3. Supplementry figures S1-S5

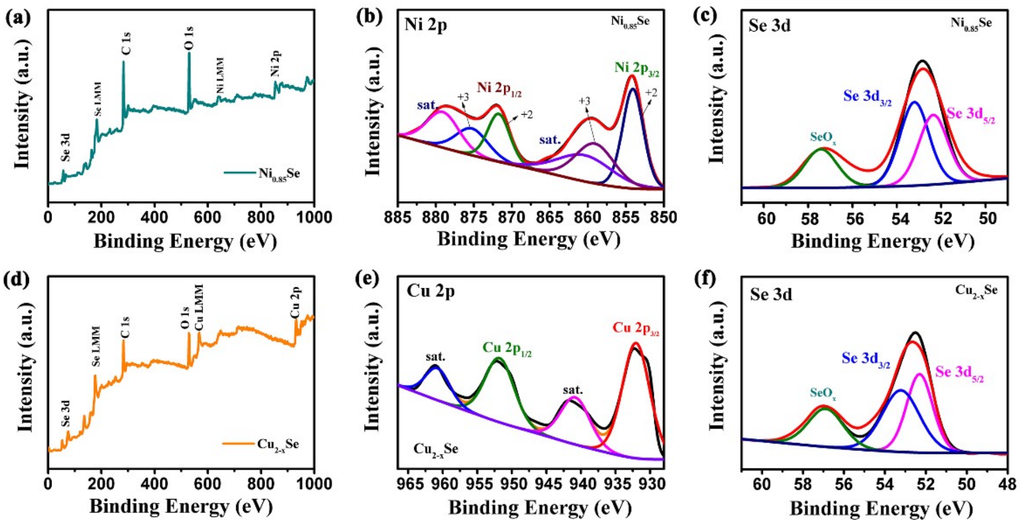

Figure S1. XPS spectra of $Ni_{0.85}Se$ (a) survey spectrum, (b) Ni 2p, (c) Se 3d; XPS spectra of $Cu_{2-x}Se$(a) survey spectrum, (b) Cu 2p, (c) Se 3d.

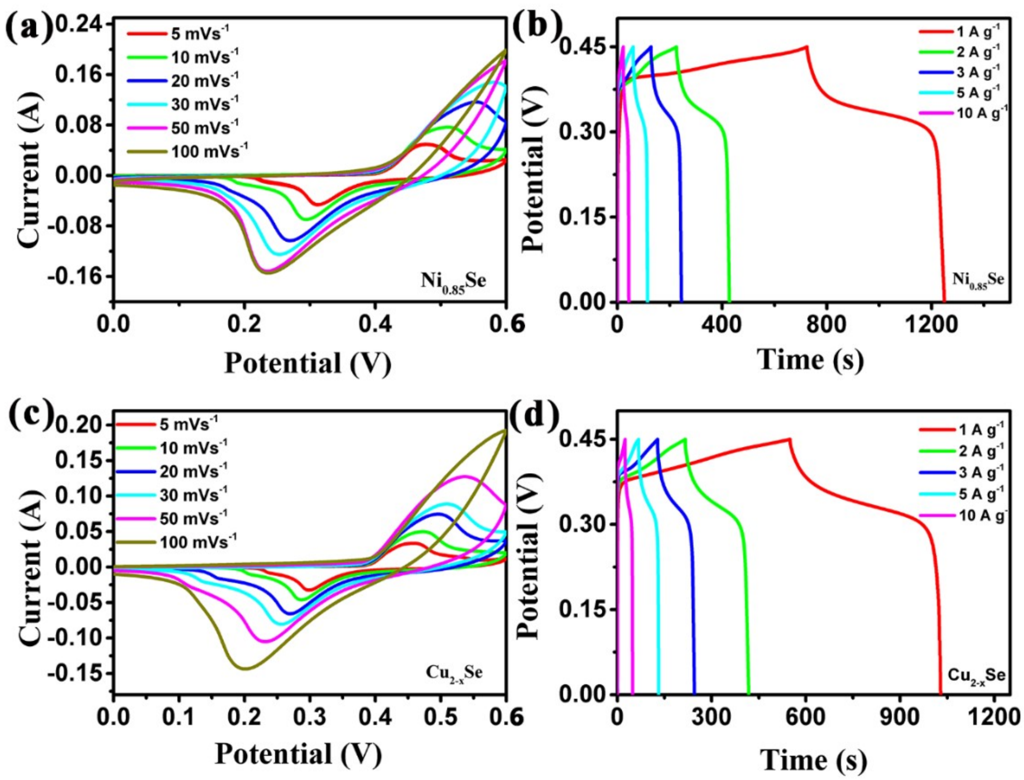

Figure S2. (a, c) CV curves of the $Ni_{0.85}Se$, $Cu_{2-x}Se$ at different scan rates, (b, d) GCD curves of the $Ni_{0.85}Se$, $Cu_{2-x}Se$ at different electric current density.

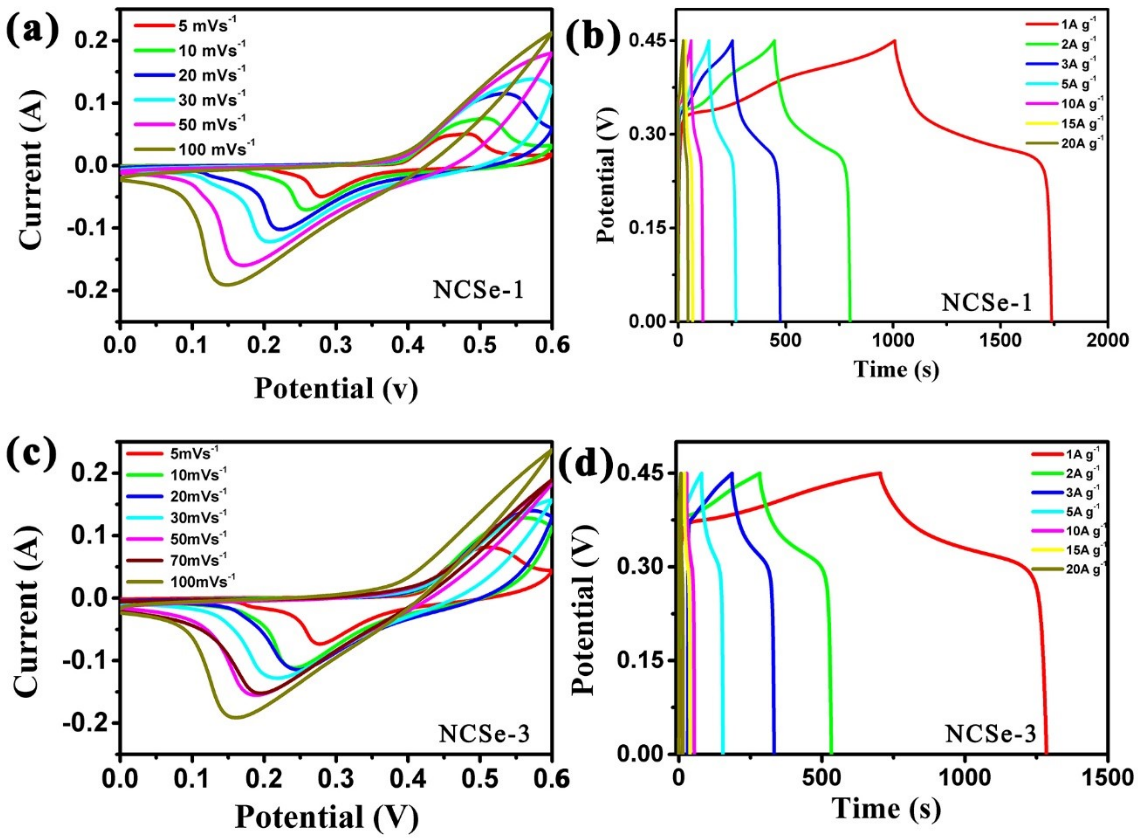

Figure S3. (a, c) CV curves of the NCSe-1, NCSe-3 at different scan rates, (b, d) GCD curves of the NCSe-1, NCSe-3 at different electric current density.

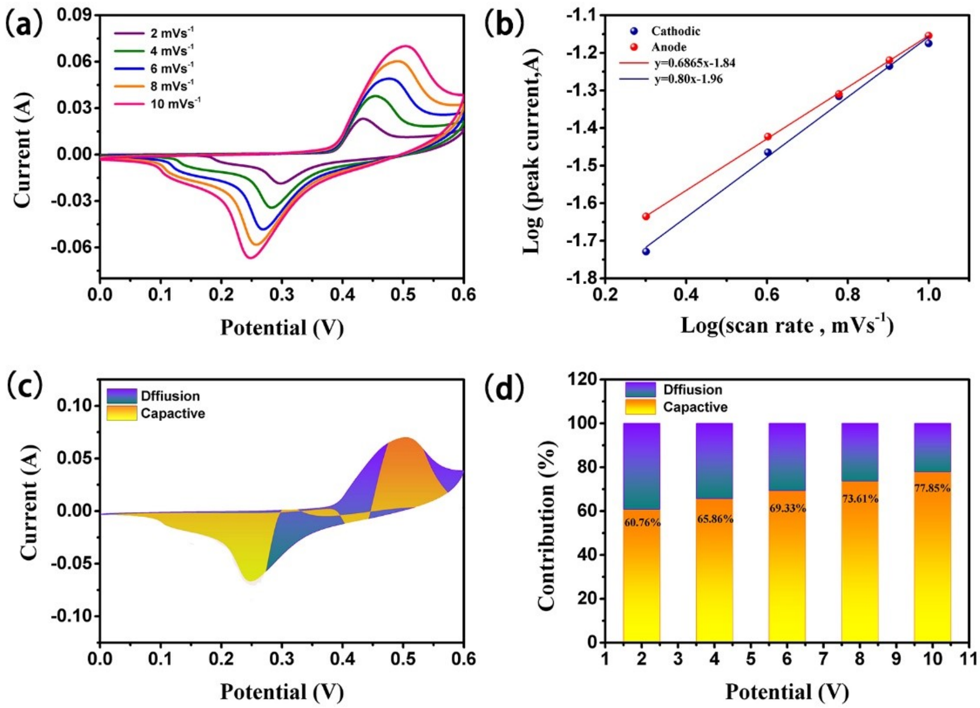

Figure S4. Quantitative capacitive analysis of energy storage behavior: (a) the CV curves of NCSe-1, (b) the curves of log(i) and log(V), (c)the capacitive contribution for NCSe-1 and diffusion contribution (blue) at a scan of 10 mV s^{-1}, (d) comparison of charge storage for NCSe-1 electrodes at different scan rates.

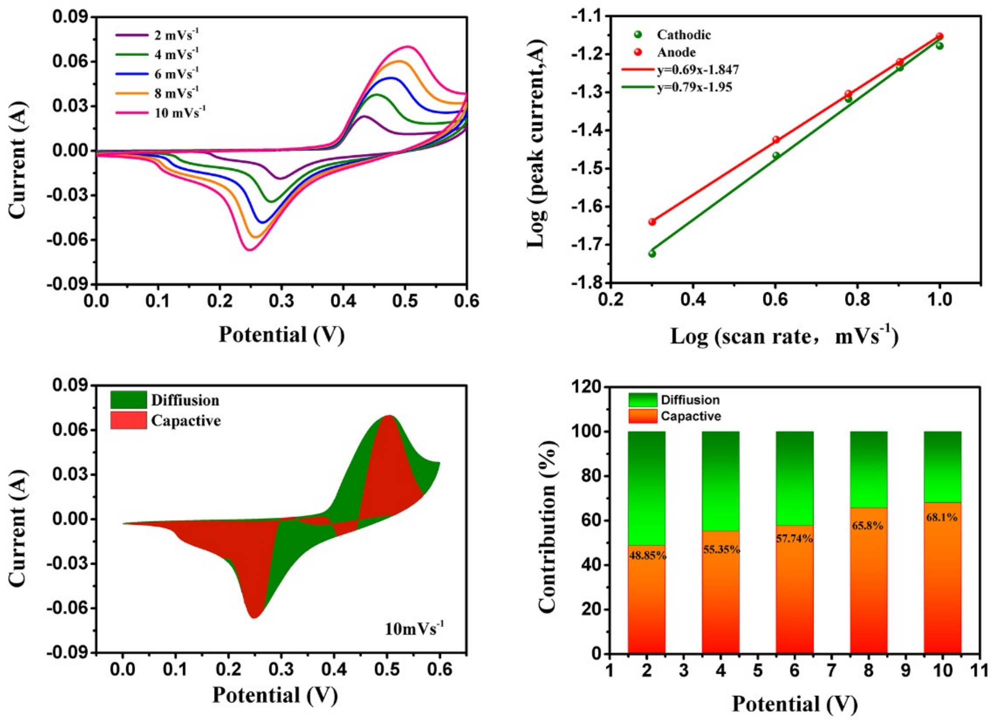

Figure S5. Quantitative capacitive analysis of energy storage behavior: (a) the CV curves of NCSe-3, (b) the curves of log(i) and log(V), (c)the capacitive contribution for NCSe-3 and diffusion contribution (green) at a scan of 10 mV s^{-1}, (d) comparison of charge storage for NCSe-3 electrodes at different scan rates.

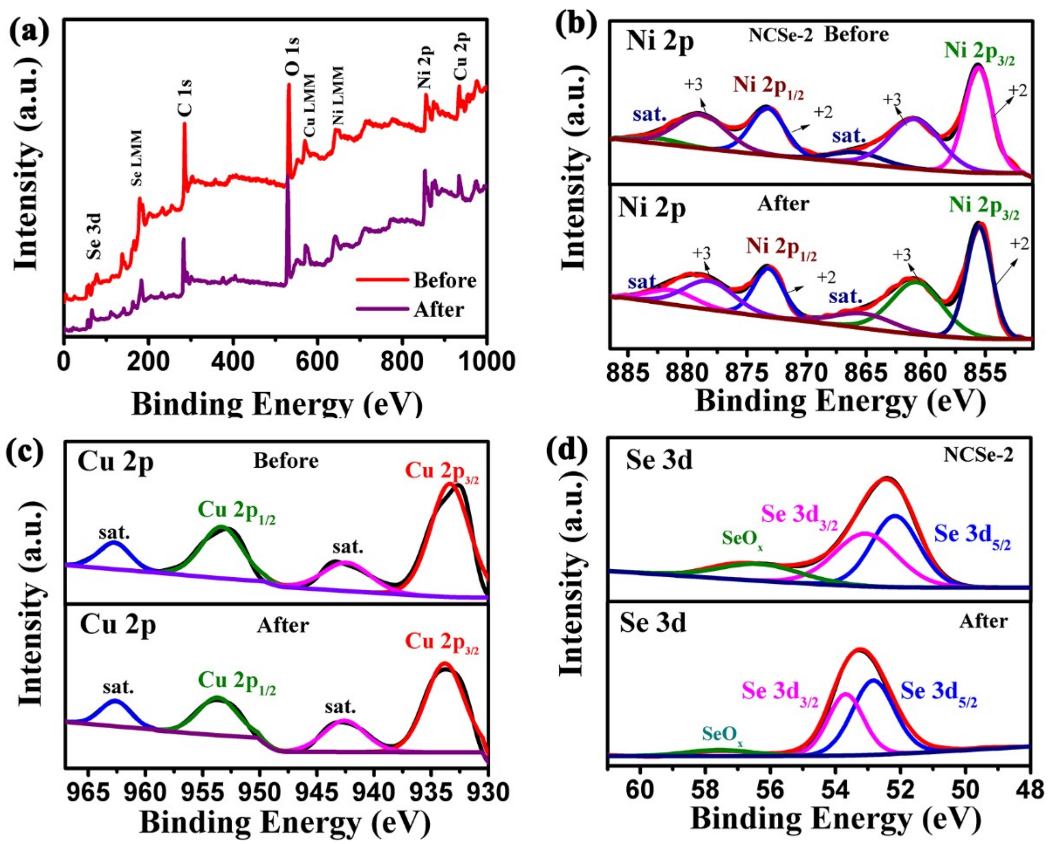

Figure S6. XPS spectra of NCSe-2 before (above) and after 8000 GCD cycles (below): (d) survey spectrum, (e) Ni 2p, (f) Cu 2p, (d) Se 3d.

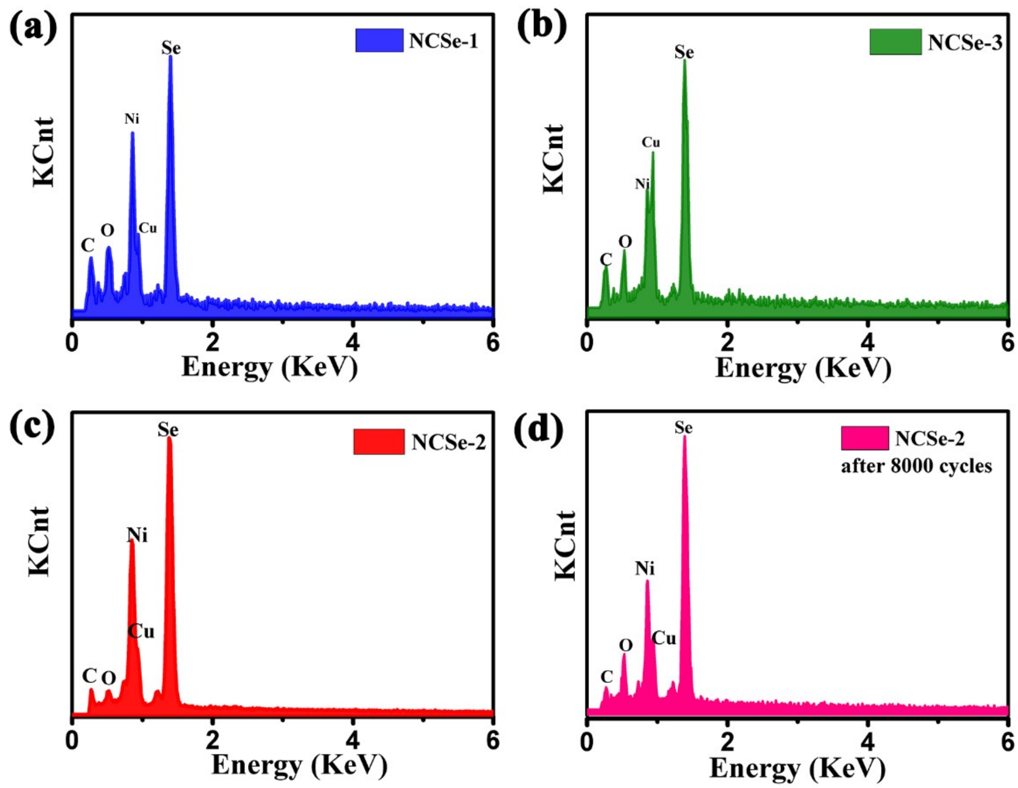

Figure S7. (a, b, c, d) EDS of the NCSe-1, NCSe-3, NCSe-2, NCSe-2 after 8000 cycles.

4.Supplementry tables S1-S4

Table S1. Elemental composition of quant results by the EDS.

	Ni (%)	Cu (%)	Se (%)	O (%)
NCSe-1	19.79	16.25	49.05	14.91
NCSe-2	33.85	15.34	44.72	6.09
NCSe-3	13.52	20.64	49.99	15.85
NCSe-2 after8000 cycle	24.85	10.28	41.05	23.82

Table S2. Elemental composition of electrodes by the XPS.

	Ni (%)	Cu (%)	Se (%)
NCSe-1	27.25	22.19	50.56
NCSe-2	35.53	16.41	48.07
NCSe-3	18.64	27.78	53.58
$Ni_{0.85}Se$	34.38	0	65.62
$Cu_{2-x}Se$	0	25.58	74.42
NCSe-2 after8000 cycle	33.48	14.25	52.27

Table S3 Comparison of the capacity performance of as-prepared $Ni_{0.85}Se@Cu_{2-x}Se$ (NCSe-2) and other metallic selenides electrode materials reported previously.

Electrode material	Special capacity	Morphology	Current density	Ref
$Ni_{0.85}Se@Cu_{2-x}Se$	nanorods	1831 F g^{-1}	1A g^{-1}	This work
Cu_7Se_4-$Cu_xCo_{1-x}Se_2$	double-shell hollow nanospherical	349.1 F g^{-1}	1 A g^{-1}	Manuscript 28
$Ni_{0.85}Se@MoSe_2$	nanostructures	774 F g^{-1}	1 A g^{-1}	Manuscript 29
$Zn_{0.67}Co_{0.33}Se$	hierarchical flower-like	2214F g^{-1}	1A g^{-1}	Manuscript 30
$Cu_{0.5}Co_{0.5}Se_2$	nanosheets	1695 F g^{-1}	1 A g^{-1}	1
Mn-Co-Se	urchin-like	1656 F g^{-1}	1 A g^{-1}	2
$CoNi_2Se_4$	flake-like	1505 F g-1	1 A g^{-1}	3
$NiCoSe_2$	ellipsoid	1408 F g^{-1}	1 A g^{-1}	4

	structure			
$Ni_{0.9}Co_{1.92}Se_4$	coral-like	510.55 C g^{-1} (1021.1 F g^{-1})	2 mA cm^{-2}	6
$(Ni,Co)Se_2$	cactus-like structure	972 F g^{-1}	2 A g^{-1}	7
Co-Cd-Se	nanorods	192 mA h g^{-1} (1382 F g^{-1})	1 A g^{-1}	5
$CoFe_2Se_4$-$CoNiSe_2$	composite	183.4 mA h g^{-1} (1320.5 F g^{-1})	1 A g^{-1}	8
$NiFe_2Se_4$	particle-like microstructure	126.9 F g^{-1}	1 A g^{-1}	9
Ni-Co-Se	hollow nanoparticles	584 C g^{-1} (1168 F g^{-1})	1 A g^{-1}	10
$Ni_{0.6}Co_{0.4}Se_2$	reed mat-like sheets	1580 F g^{-1}	1 A g^{-1}	11
$NiCo_2O_4$ @$Ni_{0.85}Se$	core-shell architecture	1454 F g^{-1}	1 A g^{-1}	13
$Co_{0.85}Se$	petal-like nanosheets	294 F g^{-1}	0.5 A g^{-1}	14
Ni_3Se_2	nanodendrite arrays	1234 F g^{-1}	1 A g^{-1}	15

Table S4 Comparison of the performance of NCSe-2//AC with those of reported HSC devices based on metallic selenides.

Supercapacitors	Specific energy	Specific power W Kg^{-1}	Ref

	(Wh Kg^{-1})		
NCSe-2//AC ASC	63.2 Wh kg^{-1}	800.1 W kg^{-1}	This work
CuCo-Se//AC	29.5 Wh kg^{-1}	332.9 W kg^{-1}	manuscript 22
$Ni_{0.85}Se@MoSe_2$//GNS	25.2 Wh kg^{-1}	420 W kg^{-1}	Manuscript 29
CCS-2h//AC	26.84 Wh kg^{-1}	700 W kg $^{-1}$	Manuscript 28
$Cu_{0.5}Co_{0.5}Se_2$//Ti_3C_2	84.17 Wh kg^{-1}	604 W kg $^{-1}$	1
Mn-Co-Se//AC	55.1 Wh kg $^{-1}$	880 W kg $^{-1}$	2
$Ni_{0.9}Co_{1.92}Se_4$//AC	26.29 Wh kg^{-1}	265 W kg $^{-1}$	6
$(Ni,Co)Se_2$/NiCo-LDH//PC	39 Wh kg $^{-1}$	1650 W kg $^{-1}$	7
Co-Cd-Se// /Fe alkaline	57.6Wh Kg $^{-1}$	10.9 kWkg $^{-1}$	5
CFS–CNS//CFS–CN	80.2 W h kg^{-1}	1000 W kg-^{1}	8
$NiFe_2Se_4$//AC	45.6 W h kg^{-1}	800 W kg^{-1}	9
Ni-Co-Se//RGO	41.8 W h kg^{-1}	750 W kg^{-1}	10
$Ni_{0.6}Co_{0.4}Se_2$//AC	44.1 W h kg^{-1}	691.3 W kg^{-1}	11
$(Ni,Cu)Se_2$ //AC	44.46 Wh kg^{-1}	797.9 W kg^{-1}	12
$NiCo_2O_4$ @$Ni_{0.85}Se$ //AC	29.3 Wh kg^{-1}	799 W kg^{-1}	13
$Co_{0\cdot 85}Se$//N-PCNs	21.1 Wh kg^{-1}	400 W kg^{-1}	14
Ni_3Se_2 -24//AC	22.3 Wh kg^{-1}	160.4 W kg^{-1}	15

5.Supplementary References:

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