Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Ultrahigh-rate, ultralong-life asymmetric supercapacitors based on few-crystalline, porous $NiCo_2O_4$ nanosheet composites

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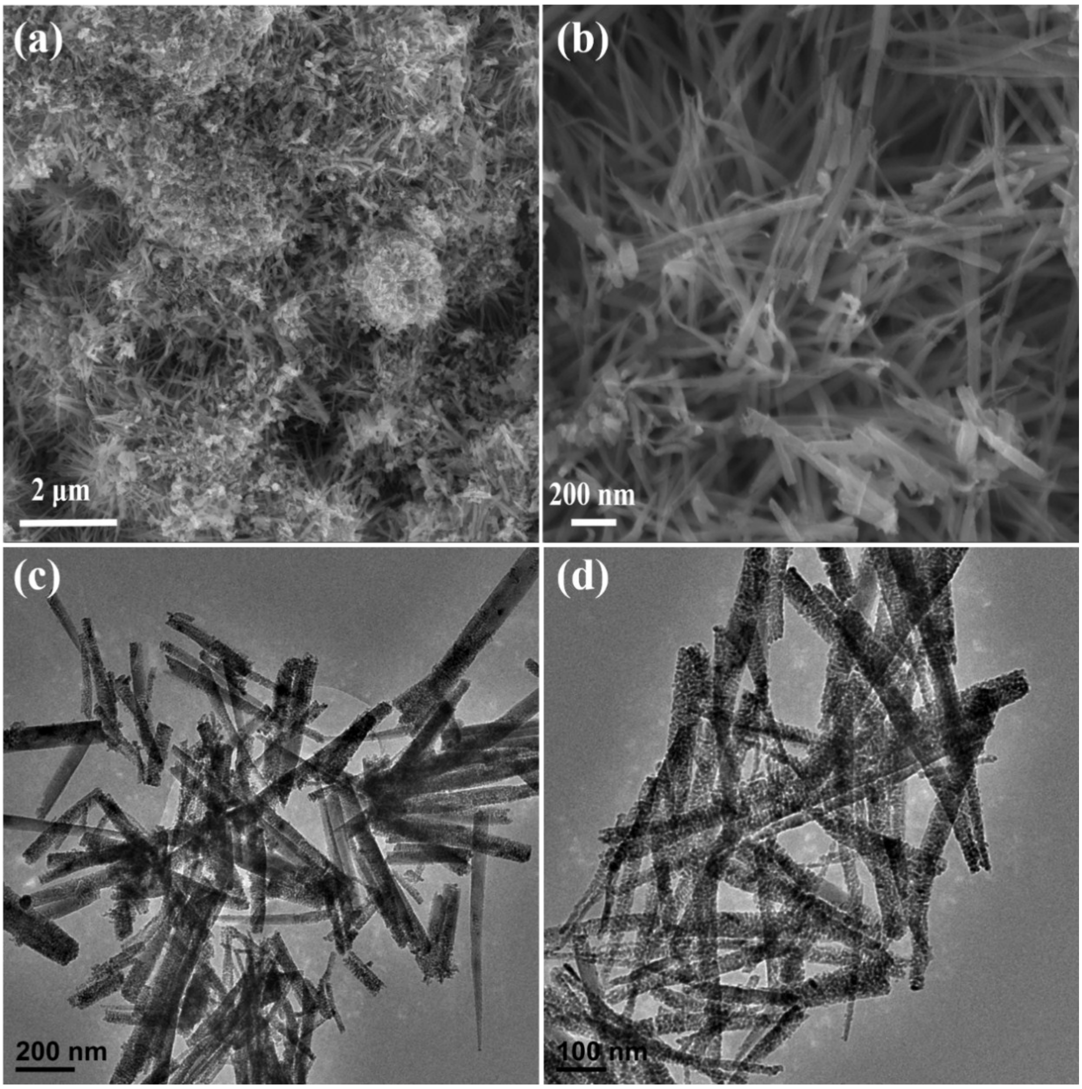

Fig. S1 FESEM images of the $NiCo_2O_4$ at (a) low and (b) high magnifications. TEM images of the $NiCo_2O_4$ at (c) low and (d) high magnifications.

Table S1 Comparison of electrochemical performance between the FCP-$NiCo_2O_4$/RGO/CNTs//AC ASC and the previously reported Ni and/or Co-based ASCs.

ASC type /Potential	**C_T (F g^{-1}) (small current)**	**C_T (F g^{-1}) (large current)**	**E_{max}**	**P_{max}**	**Cycle stability**	**Reference**
CQDs/ $NiCo_2O_4$ //AC (1.5 V)	88.9 (0.5 A g^{-1})	42.1 (40 A g^{-1}, 47.4%)	27.8 Wh kg^{-1} (128 W kg^{-1})	10.2 kW kg^{-1} (13.1 W h kg^{-1})	101.9% (5,000 cycles, 3 A g^{-1})	1
$NiCo_2O_4$/CNTs //AC (1.4 V)	105 (1 A g^{-1})	55 (20 A g^{-1}, 52.4%)	28.58 Wh kg^{-1} (700 W kg^{-1})	14.18 kW kg^{-1} (14.18 Wh kg^{-1})	Almost 100% (3,000 cycles, 2 A g^{-1})	2
$NiCo_2O_4$ @ Au nanotubes(1.45 V)	~55 (1 A g^{-1})	~15 (5 A g^{-1}, 27.3%)	19.56 Wh kg^{-1} (782.6 W kg^{-1})	2.12 kW kg^{-1} (2.75 Wh kg^{-1})	79.1% (4,000 cycles, 2 A g^{-1})	3
$NiCo_2O_4$ /MnO_2 //AC (1.4 V)	31.3 (0.25 A g^{-1})	24 (4 A g^{-1}, 76.7%)	9.4 Wh kg^{-1} (175 W kg^{-1})	2.5 kW kg^{-1} (5.8 Wh kg^{-1})	89.7% (3,000 cycles, 5 A g^{-1})	4
$NiCo_2O_4$ //AC (1.4 V)	54 (0.5 A g^{-1})	25 (8 A g^{-1}, 46.3%)	14.7 Wh kg^{-1} (175 W kg^{-1})	2.8 kW kg^{-1} (6.8 Wh kg^{-1})	85% (5,000 cycles, 1.5 A g^{-1})	5
$NiCo_2O_4$@HMRA //AC (1.5 V)	49.3 (1 A g^{-1})	20.4 (10.4 A g^{-1}, 41.5%)	15.4 Wh kg^{-1}	7.8 kW kg^{-1}	106% (2,500 cycles, 100 mV s^{-1})	6
$NiCo_2O_4$/NGN/ CNTs//NGN/CNT (1.55 V)	128 (1 A g^{-1})	80.4 (10 A g^{-1}, 62.8%)	42.7 Wh kg^{-1} (775 W kg^{-1})	15.5 kW kg^{-1} (24.7 Wh kg^{-1})	86% (10,000 cycles, 4 A g^{-1})	7
CNT@NiO//PCPs (1.6 V)	72 (0.5 A g^{-1})	28 (20 A g^{-1}, 38.9%)	25.4 Wh kg^{-1} (400 W kg^{-1})	16 kW kg^{-1} (9.8 Wh kg^{-1})	93% (10,000 cycles, 6 A g^{-1})	8
GF-CNT @ NiO //G-CNT	65.8 (1 A g^{-1})	20.1 (8 A g^{-1}, 30.5%)	23.4 Wh kg^{-1} (1060 W kg^{-1})	7.14 kW kg^{-1} (11.9 Wh kg^{-1})	81.7% (30,000 cycles, 4A g^{-1})	9
CNT/$Ni(OH)_2$ //RGO (1.8 V)	78.3 (1 A g^{-1})	58.3 (30 A g^{-1}, 74.5%)	35.2 Wh kg^{-1} (1807 W kg^{-1})	27.1 kW kg^{-1} (26.2 Wh kg^{-1})	----	10
$Ni(OH)_2$/AC/CNT // AC (1.6 V)	82.1 (0.5 A g^{-1})	~40 (10 A g^{-1}, 48.7%)	32.3 Wh kg^{-1} (504.8 W kg^{-1})	~8 kW kg^{-1} (14.2 Wh kg^{-1})	83.5% (1,000 cycles, 10 A g^{-1})	11
Ni-Co Hydroxide /Graphene/Ni Foam//AC (1.5 V)	108 (1 A g^{-1})	66.7 (10 A g^{-1}, 61.8%)	33.8 Wh kg^{-1} (750 W kg^{-1})	7.5 kW kg^{-1} (20.8 Wh kg^{-1})	84.4% (2,000 cycles, 4 A g^{-1})	12
$Ni(OH)_2$//AC (1.3 V)	153 (5 mV s^{-1})	~50 (50 mV s^{-1}, 32.7%)	35.7 Wh kg^{-1} (490 W kg^{-1})	1.67 kW kg^{-1} (12.6 Wh kg^{-1})	81%(10,000 cycles, 100 mV s^{-1})	13
Co_3O_4//Carbon (1.6 V)	101 (2 A g^{-1})	43 (10 A g^{-1}, 42.6%)	36 Wh kg^{-1} (1600 W kg^{-1})	8 kW kg^{-1} (15 Wh kg^{-1})	89% (2,000 cycles, 5 A g^{-1})	14
Co_3O_4@MnO_2 // MEGO (1.6 V)	49.8 (1 A g^{-1})	~10 (10 A g^{-1}, 20.1%)	17.7 Wh kg^{-1} (~800 W kg^{-1})	~10 kW kg^{-1} (~3.5 Wh kg^{-1})	81.1% (10,000 cycles, 3 A g^{-1})	15
FCP-$NiCo_2O_4$/RGO/ CNTs//AC (1.6 V)	**107.8 (1 A g^{-1})**	**77.5 (10 A g^{-1}, 72.0%) 66.5 (20 A g^{-1}, 61.7%) 50.1 (50 A g^{-1}, 46.5%) 45.5 (80 A g^{-1}, 42.2%)**	**38.1 Wh kg^{-1} 797.8 W kg^{-1}**	**58.1 kW kg^{-1} 13.3 Wh kg^{-1}**	**104.8% (20,000 cycles) 81.2% (50,000 cycles) 20 A g^{-1}**	**This work**

Table S2 Comparison of electrochemical performances between the FCP-$NiCo_2O_4$/RGO/CNT composite and the previously reported results based on the Ni and/or Co-based materials in a three-electrode system.

Sample	**C_s (F g^{-1}) (low current)**	**C_s (F g^{-1}) (large current)**	**Rate capability**	**Reference**
$NiCo_2O_4$/3D graphene	2300 (1 A g^{-1})	711 (20 A g^{-1})	30.9%	16
$NiCo_2O_4$ nanowires /Carbon Textiles	1283 (1 A g^{-1})	1010 (20 A g^{-1})	78.7%	17
$NiCo_2O_4$/3D graphene foam	1402 (1 A g^{-1})	1080 (20 A g^{-1})	77.0%	18
$NiCo_2O_4$/CNTs	680 (1 A g^{-1})	480 (50 A g^{-1})	70.6%	19
$NiCo_2O_4$ nanosheets @ hollow microrod arrays	678 (6 A g^{-1})	367 (47 A g^{-1})	54.1%	6
$NiCo_2O_4$ nanowires (microemulsion technique)	1197 (1 A g^{-1})	625 (8 A g^{-1})	52.2%	20
$NiCo_2O_4$ nanocrystal-based electrode	1113 (1 A g^{-1})	765 (20 A g^{-1})	68.7%	21
$NiCo_2O_4$/CNTs films	828 (1 A g^{-1})	656 (20 A g^{-1})	79.2%	2
CNS/ $NiCo_2O_4$ core-shell sub-microspheres	1420 (1 A g^{-1})	1018 (10 A g^{-1})	71.7%	22
Core-shell $NiCo_2O_4$ @ $NiMoO_4$ nanowires	1325.9 (2 mA cm^{-2})	730.9 (40 mA cm^{-2})	55.1%	23
Ni foam/N-CNT/ $NiCo_2O_4$ nanosheets	1472 (1 A g^{-1})	1074.5 (30 A g^{-1})	73%	24
Ni/Co Oxide (microsphere)	696 (1 A g^{-1})	614 (10 A g^{-1})	88.2%	25
$NiCo_2O_4$ @ $MnMoO_4$ Core-shell Flower	1118 (1 A g^{-1})	746 (10 A g^{-1})	66.7%	26
$NiCo_2S_4$ ball-in-ball hollow spheres	1036 (1 A g^{-1})	705 (20 A g^{-1})	68.5%	27
Co_3O_4/RGO	458 (0.5 A g^{-1})	416 (2 A g^{-1})	90.8%	28
Co_3O_4/RGO/CNTs	378 (2 A g^{-1})	297 (8 A g^{-1})	78.6%	29
CNTs @ NiO	996 (1 A g^{-1})	500 (20 A g^{-1})	50.2%	8
NiO/RGO/CNTs	1180 (1 A g^{-1})	840 (10 A g^{-1})	71.2%	30
FCP-$NiCo_2O_4$/RGO/CNTs	**1618 (1 A g^{-1})**	**1283.2 (10 A g^{-1}) 1164.2 (20 A g^{-1}), 1079.7 (30 A g^{-1}), 917.8 (50 A g^{-1})**	**79.3% (10A g^{-1}), 72.0% (20A g^{-1}), 66.7% (30A g^{-1}), 56.7% (50 A g^{-1})**	**This work**

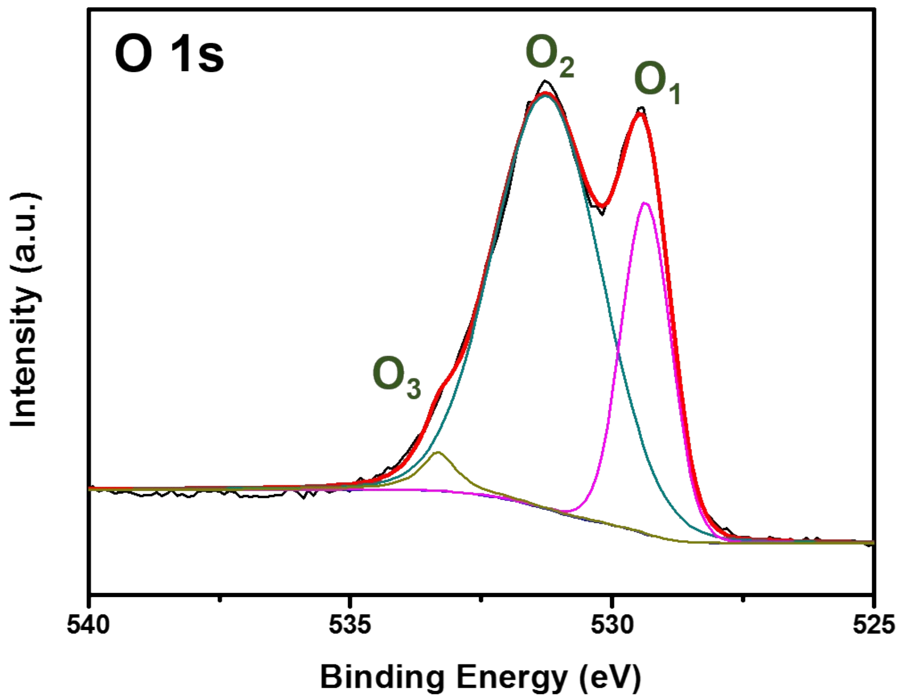

Fig. S2 XPS spectra of O 1s for the $NiCo_2O_4$ nanobelts.

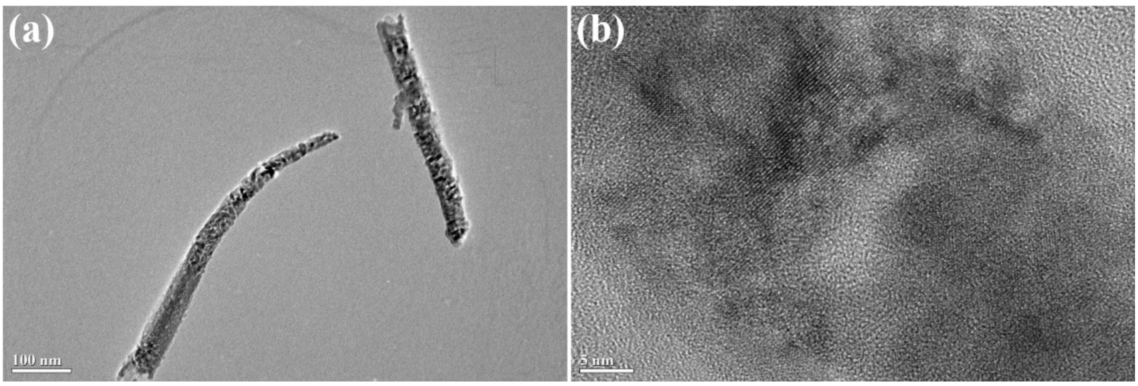

Fig. S3 HRTEM images of $NiCo_2O_4$ nanobelts at different magnifications.

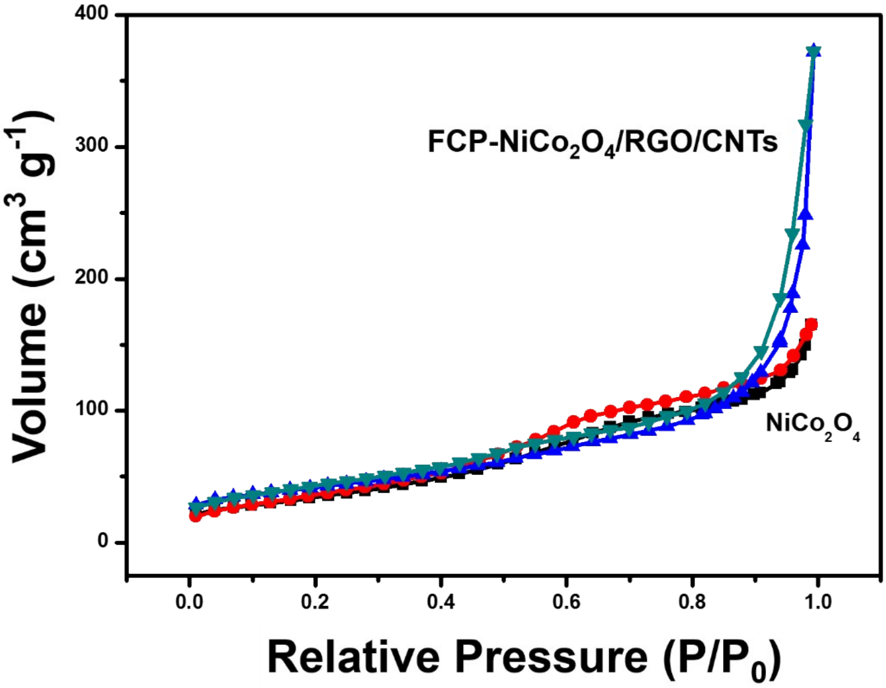

Fig. S4 Nitrogen adsorption/desorption isotherms of the FCP-$NiCo_2O_4$/RGO/CNT composite and the $NiCo_2O_4$ nanobelts.

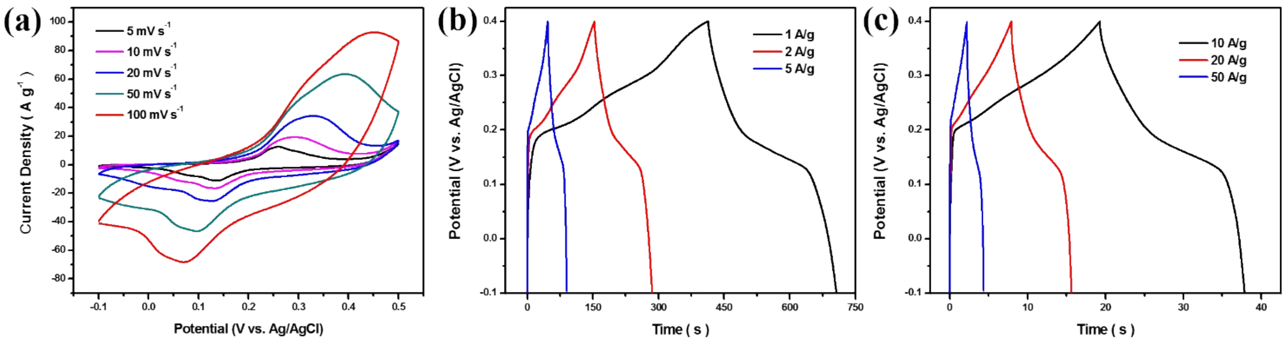

Fig. S5 (a) CV curves of the $NiCo_2O_4$ electrode at scan rates from 5 to 100 mV s^{-1}. (b) and (c) CP curves of the $NiCo_2O_4$ electrode at current densities from 1 to 50 A g^{-1}.

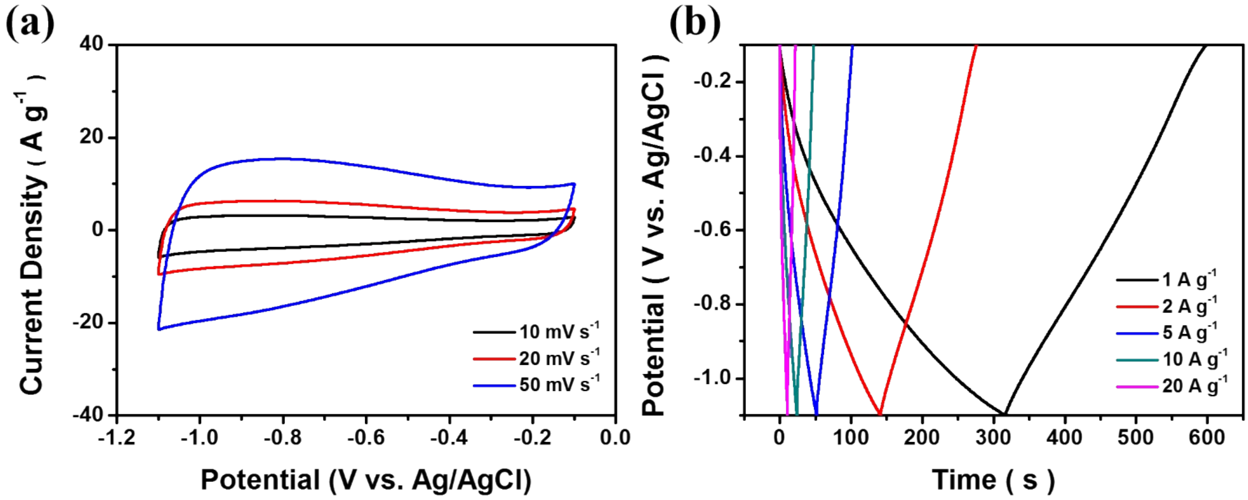

Fig. S6 (a) CV curves of AC electrode at scan rates from 10 to 50 mV s^{-1}. (b) CP curves of AC electrode at current densities from 1 to 20 A g^{-1}.

Table S3 Specific capacitance of AC electrode at current densities from 1 to 20 A g^{-1}.

Current density (A g^{-1})	Specific capacitance (F g^{-1})
1	281.5
2	268.2
5	251.5
10	235.7
20	214.2

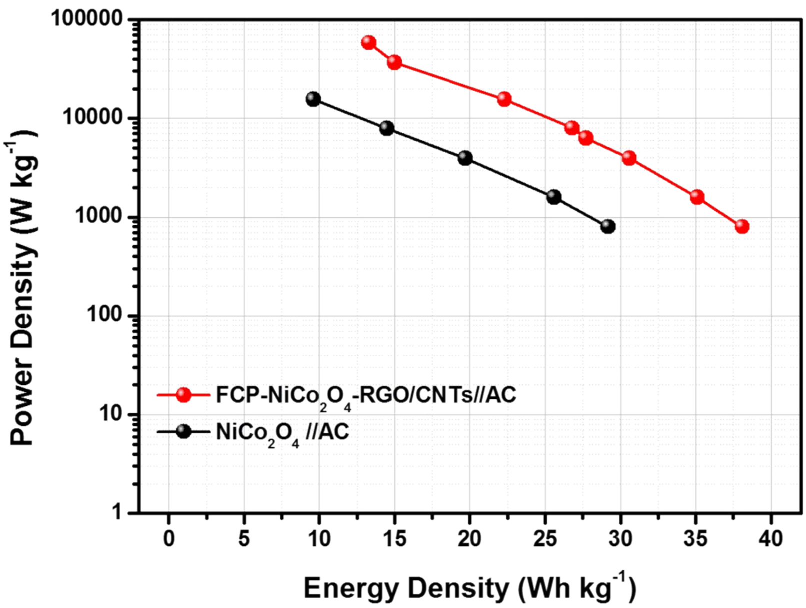

Fig. S7 A Ragone plot for $NiCo_2O_4$//AC and FCP-$NiCo_2O_4$/RGO/CNTs//AC ASC.

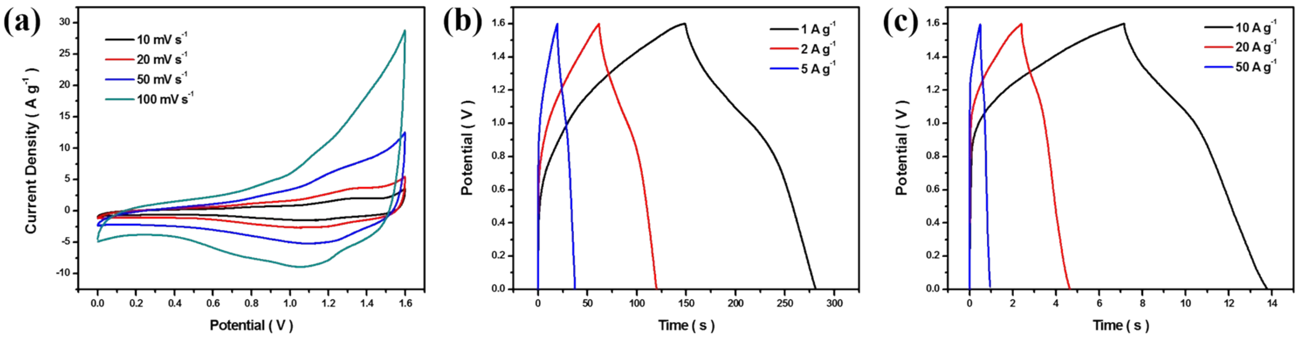

Fig. S8 Electrochemical behavior of the $NiCo_2O_4$//AC ASC. (a) and (b) CV curves of $NiCo_2O_4$//AC ASC at scan rates from 10 mV s^{-1} to 100 mV s^{-1}. (c) and (d) CP curves of the $NiCo_2O_4$//AC at current densities from 1 to 50 A g^{-1}.

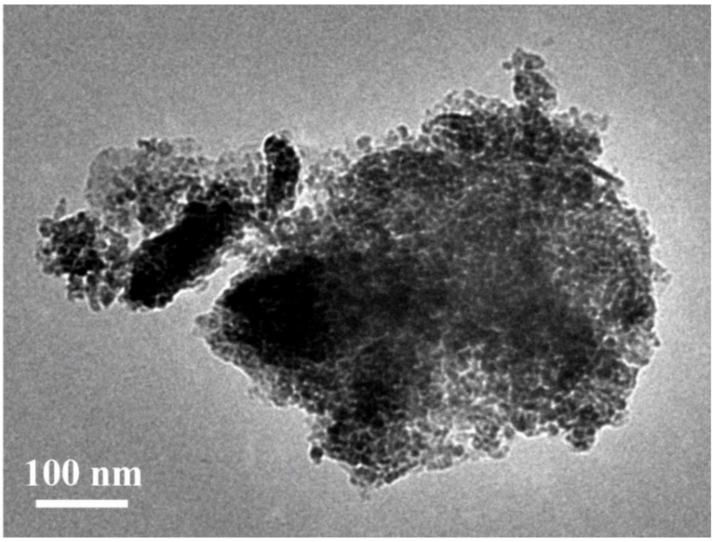

Fig. S9 A TEM image of the positive electrode (FCP-$NiCo_2O_4$/RGO/CNT composite) of our ASC device after 50,000 cycles, indicates that the $NiCo_2O_4$ held well the morphology of porous nanosheets, without visible pulverization.

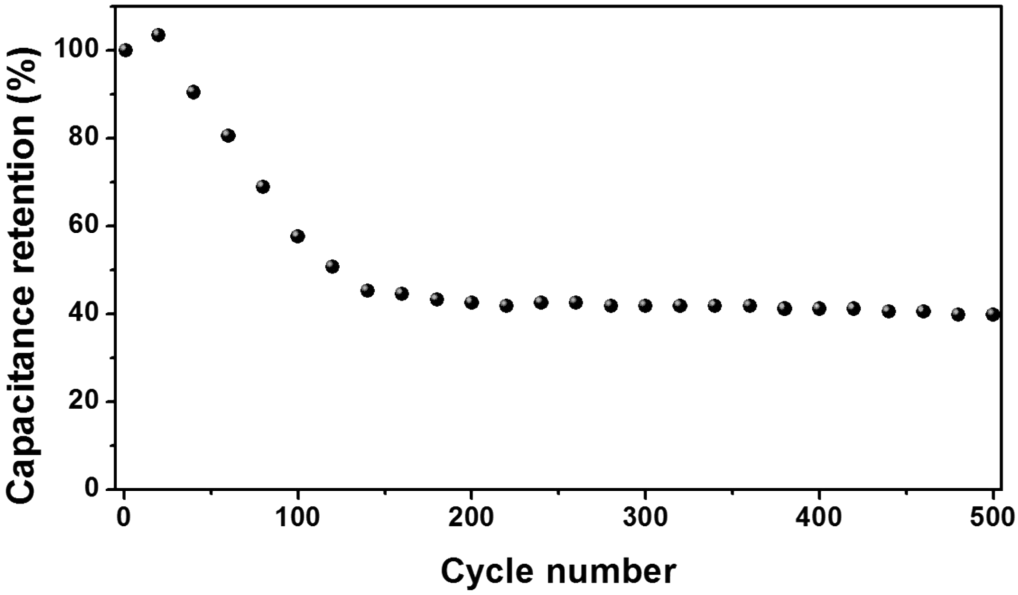

Fig. S10 Cycling stability of the $NiCo_2O_4$ //AC at 20 A g^{-1}.

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