Electronic Supplementary Information (ESI)

Cobalt-based compounds and composites as electrode materials for high-performance electrochemical capacitors

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Summary of the detailed experimental conditions (type of current collectors, electrolytes and electrolyte concentrations, potential window, and methods) to study various cobalt-based compounds and composites, and their electrochemical performance (specific capacitance and areal capacitance based on available data of mass loading, cycling life and rate capability).

Note:

CV: cyclic voltammetry; GS: galvanostatic charge-discharge measurement; DH: double hydroxides; LDH: layered double hydroxides

[a] Areal capacitance calculated based on mass loading mentioned in the paper; [b] Capacitance retention based on the highest C_m after cycling activation.

Table 1. Summary of electrochemical performance of various cobalt oxide electrodes.

Materials	Current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life (cycling no.)	Rate capability
Chemical precipitation: powdered electrodes								
[1] Co_3O_4 nanorods Co_3O_4 nanowires Co_3O_4 LPF nanostructures	Ni grid	2 M KOH	0-0.4 (SCE)	127.5 102.5 202.5	-	GS (1 A/g)	-	-
[2] Co_3O_4 nanoparticles	Ni foam	8 M KOH	0-0.6 (Hg/HgO)	320	-	CV (5 mV/s)	-	-
[3] Co_3O_4 nanowires (ref) Co_3O_4 nanowires (mw)	Ni foil	1 M KOH	0-0.6 (Hg/HgO)	336 232	-	GS (1 A/g)	86.7 % 92.8 % (2000 cyc)	68 % 54 % (GS 16 A/g)
[4] Co_3O_4 microflowers at 300 °C 400 °C 500 °C	Ni foil	6 M KOH	-0.2-0.5 (SCE)	 160 88 71	-	CV (5 mV/s)	-	 90.6 % (CV 20 mV/s)
[5] Co_3O_4 nanotubes	Ni foam	6 M KOH	-0.1-0.4 (SCE)	574	-	GS (0.1 A/g)	95 % (1000 cyc)	84.3 % (GS 1 A/g)
[6] Co_3O_4 meso-macroporous film	ITO glass	2 M KOH	0-0.45 (SCE)	453	-	GS (0.2 A/g)	-	26.3 % (GS 1 A/g)
[7] Co_3O_4 nanoparticles (NaOH) Co_3O_4 nanoparticles ($H_2C_2O_4$)	Ni foam	6 M KOH	0-0.4 (Ag/AgCl)	293.3 218.6	- -	GS (0.01 A/g)	~100 % (1000 cyc)	-
[8] Co_3O_4 mesoporous nanoparticles	Ni grid	2 M KOH	0-0.45 (SCE)	370	-	GS (5 mA)	-	93.0 % (GS 20 mA)
[9] Co_3O_4 mesoporous granules	Ni gauze	2 M KOH	0-0.4 (SCE)	427	-	GS (1.25 A/g)	93.5 % (1000 cyc)	61 % (GS, 7.5 A/g)
[10] Co_3O_4 hollow boxes	Ni foam	3 % KOH	0-0.5 (SCE)	278	-	GS (0.5 A/g)	-	63.3 % (GS, 5 A/g)
[11] Porous Co_3O_4	Ni foil	6 M KOH	-0.2-0.4 (SCE)	218	0.48 [a]	CV (2 mV/s)	-	-
[12] Co_3O_4 3D-nanonet hollow structures	Ni foam	6 M KOH	0.1-0.5 (Hg/HgO)	739	2.42 [a]	GS (1A/g)	90 % (1000 cyc)	72.1 % (GS 15 A/g)
Hydrothermal synthesis: thin film electrodes								
[13] Co_3O_4 nanoflowers	Ni foam	6 M KOH	0-0.34 (SCE)	1936.7	-	GS (0.2 A/g)	78.2 % (1000 cyc)	67.6 % (GS 3 A/g)

[14]Co_3O_4 nanoparticles	Ni sheet	2 M KOH	-0.2-0.4 (SCE)	928	0.473 [a]	GS (1.2 A/g)	93 % (2200 cyc)	84 % (GS 12 A/g)
[15]Co_3O_4 mesoporous nanowires	Ni foam	6 M KOH	0-0.5 (Hg/HgO)	1160	3.364 [a]	GS (2 A/g)	90.4 % (4700 cyc)	70.7 % (GS 20 A/g)
[16]Co_3O_4 hollow nanowires	Ni foam	1 M KOH	0-0.55 (Hg/HgO)	599	8.985 [a]	GS (2 A/g)	91 % (2 A/g, 7500 cyc) 82 % (10A/g, 7500 cyc)	73.3 % (GS 40 A/g)
[17]Co_3O_4 mesoporous nanowires	Ni foam	2 M KOH	0-0.55 (Hg/HgO)	754	3.393 [a]	GS (2 A/g)	100 % (4000 cyc)	81 % (GS 40 A/g)
[18]Co_3O_4 nanosheet @ nanowire arrays Co_3O_4 nanosheet arrays Co_3O_4 nanowire arrays	Ni foam	1 M KOH	0-0.44 (SCE)	715 390 751	5.44 [a]	GS (5 mA/cm^2)	100 % (1000 cyc)	69 % 58 % 42 % (GS 30 mA/cm^2)
[19]Co_3O_4 hierarchical porous film Co_3O_4 nanoflakes	Ni foil	2 M KOH	0-0.55 (Hg/HgO)	352 325	0.282 [a] 0.260 [a]	GS (2 A/g)	~100 % ~100 % (2500 cyc)	82.7 % 66.8 % (GS 40 A/g)
[20]Co_3O_4 porous nanowires	Ni foam	6 M KOH	-0.1-0.34 (SCE)	1019.5	1.509 [a]	GS (5 mA/cm^2)	95 % (1000 cyc)	45.7 % (GS 50 mA/cm^2)
[21]Co_3O_4 nanosheets (NS) Co_3O_4 ultrathin NS-urea Co_3O_4 ultrathin NS-HMT	Ni foam	2 M KOH	0-0.45 (SCE)	354 1081 1782	2.29 3.48 4.90	GS (5 mA/cm^2)	100 % 90 % 90 % (2000 cyc)	- 54.0 % 51.2 % (GS 30 mA/cm^2)
[22]Co_3O_4/C core-shell nanowires Co_3O_4 nanowires	Ni foam	2 M KOH	(Hg/HgO)	116 mAh/g 81 mAh/g	- -	GS (4 A/g)	- -	82.8 % (GS 20 A/g) 72.8 %
Hydrothermal synthesis: powdered electrodes								
[23]Co_3O_4 nanosheets (85 %)	Ni grid	3 M KOH	0-0.6 (SCE)	92	-	GS (5 mA/cm^2)	-	93 % (GS 20 mA/cm^2)
[24]Co_3O_4 porous nanorods (63.5 %)	Pt foil	2 M KOH	-0.25-0.55 (SCE)	281	-	CV (5 mV/s)	-	-
[25]Co_3O_4 porous nanorods (70 %)	Ni mesh	6 M KOH	0-0.4 (Ag/AgCl)	456	2.28 [a]	GS (1 A/g)	-	-
[26]Co_3O_4 nanoneedles Co_3O_4 nanoleaves Co_3O_4 microparticles (80 %)	GCE	2 M KOH	0-0.5 -0.15-0.45 -0.15-0.45	111 44 62	-	GS (2.5 mA/cm^2)	88.2 % 86.9 % 80 % (1000 cyc)	-
[27]Co_3O_4 long nanowires	Ni foam		-0.1-0.6	260	-	GS	98 %	65.8 %

(80 %)			(SCE)			(2 A/g)	(2000 cyc)	(GS 15 A/g)
[28]Co_3O_4 cubes (80 %)	Ni mesh	6 M KOH	0-0.45 (SCE)	348.7	-	CV (5 mV/s)	-	-
[29]Co_3O_4 ultralayers (80 %)	Ni foil	1 M KOH	-0.05-0.45 (Hg/HgO)	604	0.604 [a]	GS (4 A/g)	-	59.4 % (GS 32 A/g)
[30]Co_3O_4 superstructures (83.33 %)	Ni grid	3 M KOH	-0.1-0.45 (SCE)	614	-	GS (1 A/g)	77 % (5000 cyc)	87.3 % (GS, 4 A/g)
[31]Co_3O_4 nanosheets	graphite	2 M KOH	-0.1-0.5 (Ag/AgCl)	176.8	-	GS (1 A/g)	-	88.2 % (GS, 10 A/g)
[32]CoO crystallites	Ni grid	2 M KOH	0-0.5 (SCE)	88	-	CV (10 mV/s)	-	-
[33]Co_3O_4 nanowires	Ni foam	3 M KOH	0-0.47 (Hg/HgO)	163	-	GS (1 A/g)	80 % (1000 cyc)	73 % (GS, 4 A/g)
[34]Co_3O_4 twin spheres with urchin-like structures	Ni foam	6 M KOH	-0.05-0.35 (SCE)	781	-	GS (0.5 A/g)	97.8 % (1000 cyc)	78.2 % (GS, 8 A/g)
[35]Co_3O_4 nanowalls	Ni foam	6 M KOH	-0.05-0.35 (SCE)	997	-	GS (0.5 A/g)	92.3 % (1000 cyc)	76.1 % (GS, 8 A/g)
Sol-gel synthesis: powdered electrodes								
[36]$Co(OH)_2$ xerogel Co_3O_4 xerogel	Ni gauze	1 M KOH	0-0.45 (SCE)	291 ~260	1.222 [a] 1.092 [a]	GS (2.26 mA/cm^2)	-	-
[37]Co_3O_4 aerogel (200 °C) Co_3O_4 aerogel (300 °C) Co_3O_4 aerogel (400 °C)	graphite	1 M NaOH	0.23-0.53 (Ag/AgCl)	623 239 174	0.623 [a] 0.239 [a] 0.174 [a]	CV (25 mV/s)	96 % (1000 cyc)	73 % (CV 50 mV/s compared to 5 mV/s)
[38]Co_3O_4 cryogel	Ni foam	2 M KOH	-0.05-0.45 (Ag/AgCl)	742.3	1.485 [a]	GS (0.5 A/g)	86.2 % (2000 cyc)	54.4 % (GS 20 A/g)
Chemical bath deposition: thin film electrodes								
[39]Co_3O_4 nanowires	Ni foam	6 M KOH	0-0.35 (SCE)	746	11.936[a]	GS (5 mA/cm^2)	86 % (500 cyc)	76.1 % (GS 30 mA/cm^2)
[40]Co_3O_4 nanowires Ag coated-Co_3O_4 nanowires	Ti	1 M KOH	-0.4-0.4 (SCE)	922 1006	-	GS (2 A/g)	95 % 95 % (5000 cyc)	54.2 % 83.3 % (GS 10 A/g)
[41]Co_3O_4 thin film	Cu	1.5 M KOH	-0.4-0.5 (SCE)	118	0.051 [a]	CV (50 mV/s)	-	-
[42]Co_3O_4 thin film	ITO glass	2 M KOH	0-0.45 (SCE)	227	-	GS (0.2 A/g)	65 % (1000 cyc)	67.0 % (GS 1.4 A/g)
[43]Co_3O_4 nanonets	Ni foam	1 M NaOH	-0.2-0.6 (Hg/HgO)	1090	1.526 [a]	CV (10 mV/s)	-	~ 68 % (CV 50 mV/s)
Electrochemical deposition: thin film electrodes								
[44, 45]Co_3O_4 thin film	Au foil	3 wt% KOH	-0.35 to -0.05	79	-	CV	-	-

			0-0.5 (SCE)	164		(20 mV/s)		
[46] Co_3O_4-CTAB Co_3O_4-SDS Co_3O_4-without surfactant	ITO glass	1 M NaOH	0-0.45 (Ag/AgCl)	491 373 255	-	GS (1 A/g)	-	-
[47] Co_3O_4 nanowalls Co_3O_4 dense film	Ni foam	1 M KOH	0-0.55 (Hg/HgO)	325 230	0.520 [a] 0.414 [a]	GS (2 A/g)	-	76.0 % 72.6 % (40 A/g)
[48] Co_3O_4 nanoplates (scrapped from stainless steel)	Ni foam	1 M KOH	-0.2-0.5 (Ag/AgCl)	465.5	-	CV (5 mV/s)	96.5 % (500 cyc)	63.2 % (50 mV/s)
[49] Co_3O_4 monolayer hollow-sphere arrays	Ni foil	1 M KOH	0-0.55 (Hg/HgO)	358	0.179 [a]	GS (2 A/g)	~100 % (4000 cyc)	85.2 % (40 A/g)
[50] Co_3O_4 porous nanowalls	Ni foam	1 M KOH	0-0.55 (Hg/HgO)	443	-	GS (2 A/g)	94.3 % (3000 cyc)	75.4 % (40 A/g)
[51] Co_3O_4 mesoporous nanosheets	Ni foam	2 M KOH	0-0.45 (SCE)	2735	3.829 [a]	GS (2 A/g)	~99 % (3000 cyc)	53.8 % (10 A/g)
Spray deposition: thin film electrodes								
[52] Co_3O_4 thin film	FTO glass	2 M KOH	0-0.6 (SCE)	74	0.032 [a]	CV (5 mV/s)	-	-
[53] Co_3O_4 nanostructured thin film	Stainless steel	6 M KOH	0-0.35 (Ag/AgCl)	~250	-	GS (~0.1 A/g)	72.2 % (1000 cyc)	~60 % (GS ~4 A/g)
Other methods								
[54] Co_3O_4 nano/micro superstructures	Ni grid	6 M KOH	0-0.35 (SCE)	208	-	GS (1 A/g)	97 % (1000 cyc)	-

Table 2. Summary of electrochemical performance of various cobalt hydroxide and oxyhydroxide electrodes.

Materials	Current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life (cycling no.)	Rate capability
Chemical precipitation: powdered electrodes								
[55]α-$Co(OH)_2$ mesoporous particles	Ni grid	1 M KOH	-0.15-0.45 (SCE)	341	2.558 [a]	GS (5 mA/cm^2)	81 % (700 cyc)	-
[56]β-$Co(OH)_2$ nanowhiskers	Ni grid	2 M KOH	-0.15-0.5 (SCE)	325	4.875 [a]	GS (20 mA/cm^2 or 1.33 A/g)	93 % (1000 cyc)	85.8 % (80 mA/cm^2 or 5.33 A/g)
[57]β-$Co(OH)_2$ sheets	Ni foam	1 M KOH	-0.15-0.45 (SCE)	416.7	1.063 [a]	GS (5 mA)	78 % (500 cyc)	-
[58]α-$Co(OH)_2$-Cl^- α-$Co(OH)_2$- NO_3^- α-$Co(OH)_2$-CH_3COOH^- α-$Co(OH)_2$-SO_4^{2-}	Ni foam	6 M KOH	-0.1-0.4 (Hg/HgO)	697 638 526 420	-	GS (1 A/g)	73 % 56 % 57 % 48 % (100 cyc)	-
α-$Co(OH)_2$-benzoate α-$Co(OH)_2$-DS α-$Co(OH)_2$-NO_3^- (nanocones)	Ni foam	2 M KOH	0-0.45 (SCE)	852 1055 630	0.852-1.704 [a] 1.055-2.110 [a] 0.630-1.260 [a]	GS (1 A/g)	72 % 95 % 81 % (2000 cyc)	16.8 % 39.8 % 11.4 % (10 A/g)
[59]α-$Co(OH)_2$ nanoflakes	Ni gauze	2 M KOH	-0.2-0.4 (SCE)	735	5.88 [a]	GS (5 mA/cm^2)	-	82.9 % (30 mA/cm^2)
[60]β-$Co(OH)_2$ triangle taper Co_3O_4 mesoporous triangle taper	Ni foam	2 M KOH	-0.3-0.5 -0.2-0.5 (SCE)	137.6 91.5	~0.894 [a] ~0.595 [a]	CV (5 mV/s)	-	71.2 % 77.5 % (CV 50 mV/s)
[61]Co/$Co(OH)_2$ core-shell structure (thin film electrodes)	Co foam (the core)	2 M KOH	0-0.5 (Ag/AgCl)	525	-	GS (0.5 A/g)	81. 5 % (2000 cyc)	-
Hydrothermal synthesis: powdered and thin film electrodes								
[62]α-$Co(OH)_2$ nanoflakes	Ni grid	2 M KOH	0-0.5 (Ag/AgCl)	248	1.240 [a]	GS (0.5 A/g)	-	79.4 % (GS 2 A/g)
[63]β-$Co(OH)_2$ urchin-like arrays of nanowires [64]β-$Co(OH)_2$ urchin-like arrays of nanobelts	Ni grid	3 M KOH	-0.3-0.45 (SCE)	421 434	3.158 [a] 3.255 [a]	GS (10 mA/cm^2 or 1.33 A/g) GS (10 mA/cm^2 or	96.4 % (1000 cyc) 92.1 % (1500 cyc)	87.9 % (40 mA/cm^2 or 5.33 A/g) 84.1 % (40 mA/cm^2 or 5.33

[65]α-$Co(OH)_2$ mesocrystal nanosheets				506	3.795 [a]	1.33 A/g) GS (10 mA/cm^2 or 1.33 A/g)	97.0 % (2000 cyc)	A/g) 84.4 % (40 mA/cm^2 or 5.33 A/g)
[66]α-$Co(OH)_2$ long nanowire arrays (thin film electrode)	Graphite	2 M KOH	-0.1-0.45 (SCE)	642.5	0.643 [a]	GS (1 A/g)	~100 % (5000 cyc)	51.5 % (20 A/g)
[67]β-$Co(OH)_2$ nanocone arrays	Ni foam	2 M KOH	0-0.5 (Hg/HgO)	562	1.967 [a]	GS (2 A/g)	88 % (3000 cyc)	67.1 % (32 A/g)
Electrochemical deposition: thin film electrodes								
[68]α-$Co(OH)_2$ nanosheets	Stainless steel	1 M KOH	0-0.4 (Ag/AgCl)	881	0.705 [a]	GS (1 A/g)	91 % (2000 cyc)	87.6 % (10 A/g)
[69, 70] α-$Co(OH)_2$ mesoporous nanosheets α-$Co(OH)_2$ nanosheets	Ti plate	2 M KOH	-0.1-0.45 (SCE)	1084 370	- -	GS (4 A/g)	95.1 % (500 cyc) -	67.1 % (48 A/g) -
[71]α-$Co(OH)_2$ mesoporous nanosheets	Ni foam	2 M KOH	-0.1-0.45 (SCE)	2646	-	GS (4 A/g)	96.1 % (300 cyc)	85.9 % (48 A/g)
[72]β-$Co(OH)_2$ nanoflakes	Ni foam	5.5 M KOH	-0.05-0.5 (Hg/HgO)	3254.5	1.627 [a]	GS (5 A/g)	34 % (300 cyc)	73.1 % (60 A/g)
[73]Amorphous $Co(OH)_2$ nanosheets	Stainless steel	1 M NaOH 0.1 M NaOH 0.05 M NaOH	0-0.60 0-0.75 0-0.85 (Hg/HgO)	487 390 375	0.487 [a] 0.390 [a] 0.375 [a]	GS (10 A/g)	-	-
[74]Amorphous $Co(OH)_2$ nanoflakes	Stainless steel mesh	1 M KOH	~0-0.42 (SCE)	534 (at 0.62 mg/cm^2)	0.331 [a] (at 0.62 mg/cm^2)	GS (0.1 mA/g)	81 % (3000 cyc)	85 % (from 0.714 to 7.143 A/g)
[75]$Co(OH)_2$ nanoflakes (water-ethanol) $Co(OH)_2$ nanoflakes (water)	Ni foam	2 M KOH	0-0.4 (SCE)	2369 1035	-	GS (2 A/g)	91 % (350 cyc)	40.5 (32 A/g)
[76]α-$Co(OH)_2$ nanosheets with 0 % NMP with 10 % NMP with 20 % NMP with 30 % NMP	Stainless steel	1 M KOH	-0.1-0.45 (Ag/AgCl)	 473 571 651 473	 0.350 [a] 0.423 [a] 0.482 [a] 0.350 [a]	GS (2 A/g)	 - - 76 % (500 cyc)	 - - 75.2 % (CV 50 mV/s to 5 mV/s)
[77]α-$Co(OH)_2$ nanosheets	Ni foam	1 M KOH	-0.1-0.45 (SCE)	1473	-	GS (2 A/g)	88 % (1000 cyc)	67.0 % (GS 32 A/g)
[78]Co compound nanowires	ITO glass	0.1 M LiOH	0.05-0.55	420	-	GS	~100%	-

			(SCE)			(0.5 mA/cm^2)	(1000 cyc)	
[79]α-$Co(OH)_2$ mesoporous nanosheets	Ti/Si	1 M KOH	-0.1-0.5 (Ag/AgCl)	993	-	GS (1 A/g)	-	81.5 % (GS 20 A/g)
[80]CoOOH nanoflakes	Ni foil	1 M KOH	-0.15-0.4 (SCE)	200	-	CV (10 mV/s)	-	79.1 % (CV 250 mV/s) 63.6 % (CV 500 mV/s)
[81]CoOOH nanoflakes	stainless steel	1 M KOH	0.2-0.45 (SCE)	449	-	CV (5 mV/s)	56 % (10000 cyc)	-
Chemical bath deposition: thin film electrodes								
[82]$Co(OH)_2$ nanorods	Ni foam	1 M KOH	-0.2-0.5 (Ag/AgCl)	1116	-	GS (2 A/g)	-	37.8 % (10 A/g)

Table 3. Summary of electrochemical performance of various cobalt sulfides.

Materials	**Current collector**	**Electrolyte**	**Potential window (V)**	**C_m (F/g)**	**C_a (F/cm^2)**	**Method**	**Cycle life (cycling no.)**	**Rate capability**
[83] CoS_x amorphous particles	Ni gauze	6 M KOH	-0.3-0.35 (SCE)	475	6.65	GS (5 mA/cm^2)	91 % (100 cyc)	77.6 % (GS 50 mA/cm^2)
[84] CoS nanowires	Ni foam	3 M KOH	-0.3-0.4 (SCE)	508	-	GS (2.5 mA/cm^2)	81.2 % (500 cyc)	74.2 % (GS 20 mA/cm^2)
[85] CoS_x amorphous nanoparticles	Ni foam	2 M KOH	-0.30-0.45 (SCE)	910	-	GS (0.4 A/g)	-	71 % (GS 4 A/g)
[86] CoS spheres	Ni foil	2 M KOH	-0.2-0.55 (Hg/HgO)	363	-	CV (5 mV/s)	67 % (300 cyc)	87 % (CV 50 mV/s)
[87] CoS flowers	Ni foam	6 M KOH	-0.7-0.7 (SCE)	389	-	GS (5 mA/cm^2)	-	71.2 % (GS 50 mA/cm^2)
[88] $Co_{1-x}S$ hierarchical microtubes	Ni foam	6 M KOH	-0.3-0.35 (SCE)	201	-	GS (5 mA/cm^2)	-	-
[89] CoS hollow nanosheets	FTO substrate	1 M KOH	0-0.47 (SCE)	138	1.35	GS (2 mA/cm^2)	-	-
[90] $CoS_{1.097}$ hierarchical flowers	Ni foam	2 M KOH	0-0.5 (SCE)	555	-	GS (5 mA/cm^2)	98 % (2500 cyc)	83.6 % (GS 200 mA/cm^2)
[91] CoS_2 ellipsoids	Ni foam	2 M KOH	-0.1-0.4 (SCE)	1040	-	GS (0.5 A/g)	66 % (5 A/g) 44 % (2.5 A/g) (1000 cyc)	72.1 % (5 A/g)
[92] CoS nanosheets	Ni foam	1 M KOH	-0.1-0.45 (Ag/AgCl)	1471	0.588 [a]	GS (4 A/g)	~100 % (1000 cyc)	88.8 % (40 A/g)

Table 4. Summary of electrochemical performance of other cobalt compounds.

Materials	**Current collector**	**Electrolyte**	**Potential window (V)**	**C_m (F/g)**	**C_a (F/cm^2)**	**Method**	**Cycle life (cycling no.)**	**Rate capability**
[93]Co-MOF film	ITO glass	1 M LiOH	0-0.5 (Ag/AgCl)	206.76	-	GS (0.6 A/g)	98.5 (1000 cyc)	-
[94]$Na_{0.6}CoO_2.yH_2O$ $Li_{0.5}CoO_2$	glassy carbon	10 M NaOH	-0.45-0.28 (Ag/AgCl)	440	-	CV (20 mV/s)	-	-
[95]Cobalt carbonate hydroxide Co-Al-CO_3 LDH	Ni foam	2 M NaOH	0-0.45 (SCE)	1075 387	8.6 4.06 [a]	GS (5 mA/cm^2)	92 % (2000 cyc) -	72.4 % 56.8 % (GS, 50 mA/cm^2)
[96]$NH_4CoPO_4.H_2O$	Ni foam	3 M KOH	0-0.4 (SCE)	369.4	-	GS (0.625 A/g)	99.7 % (400 cyc)	-
[97]$Co_{11}(HPO_3)_8(OH)_6$ nanoribbons	Ni foam	3 M KOH	0-0.6 (SCE)	312	-	GS (1.25 A/g)	89.4 % (3000 cyc)	63.5 % (GS, 12.5 A/g)

Table 5. Summary of electrochemical performance of various cobalt-based LDHs.

Materials	Current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life (cycling no.)	Rate capability
[98]Co/Ni-Al LDHs	Ni grid	6 M KOH	0-0.5 (Hg/HgO)	960	19.2 [a]	GS (0.4 A/g)	-	-
[99]Co/Ni-Al LDHs/TiO_2 nanotubes				1053	5.265 [a]	GS (5 mA/cm^2)	-	-
[100]Co-Al LDH (BA)	Ni foam	1 M KOH	-0.2-0.55	212.2	-	GS	86.1 % (1000)	74.4 %
Co-Al LDO			(SCE)	199.9	-	(0.25 A/g)	93.5 % (781)	74.7 %
Co-Al LDH (OH)				190.9	-		100 % (1000)	69.3 % (2 A/g)
[101]Co-Al LDHs (OH)	Ni foam	1 M LiOH	-0.2-0.5 (SCE)	322	-	GS (0.5 A/g)	69.8 % (1000 cyc)	82.9 % (5 A/g)
[102]Co-Al LDHs	Ni foam	1 M KOH	-0.1-0.5	226	-	GS	-	-
		1 M KOH + 0.1 M $K_3Fe(CN)_6$	(SCE)	712	-	(2 A/g)	67.0 % (200)	-
		1 M KOH + 0.1 M $K_4Fe(CN)_6$		317	-		95.9 % (200)	-
[103]Co-Al LDHs	Ni foam	1 M KOH	-0.1-0.5	447	-	GS	99 %	-
Co-In LDHs			-0.2-0.5	159	-	(1 A/g)	99 %	-
Co-Cr-LDHs			-0.1-0.5 (SCE)	78	-		96 %	-
[104]Co-Al LDHs	Ni foam	6 M KOH	-0.15-0.55 (Hg/HgO)	684	13.68 [a]	GS (60 mA/g)	80 % (1000 cyc)	-
[105]Co-Al LDHs	ITO glass (pretreated)	1 M NaOH	0-0.55 (Hg/HgO)	667	-	GS (25 μA/g)	93 % (3000 cyc)	94.5 % (GS 250 μA/g)
[106]$Co_{0.75}$-$Al_{0.25}$ LDHs				833			95 % (2000 cyc)	-
[107]$Co_{0.72}Ni_{0.28}$ LDHs	stainless steel	1 M KOH	0-0.4 (Ag/AgCl)	2104	0.438 [a]	GS (1 A/g)	-	-
$Ni(OH)_2$				323	0.067 [a]		-	-
$Co(OH)_2$				860	0.179 [a]		-	-
[108]Co-Al LDHs				843	0.176 [a]		-	-
[109]CoNiAl LDHs				1263	1.053		87 % (1000 cyc)	-
[110]Co-Ni LDHs	Ni foam	6 M KOH	0-0.5 (Hg/HgO)	1809	-	GS (1 A/g)	90.2 % (1000 cyc)	86.2% (GS 10A/g)
$Co(OH)_2$				638				
$Ni(OH)_2$				1399				
[111]Zn-Co LDHs	ITO glass	3 M KOH	-0.1-0.45 (SCE)	~160-170	-	GS (1 A/g)	-	-

[112] $Co(OH)_2$ $Co_{0.75}$-$Ni_{0.25}(OH)_2$ $Co_{0.5}$-$Ni_{0.5}(OH)_2$ $Co_{0.25}$-$Ni_{0.75}(OH)_2$ $Ni(OH)_2$	graphite	1 M KOH	0-0.4 (Ag/AgCl)	490 1100 1580 1400 740	-	GS (10 A/g)	98.7 % (100 cyc)	-
[113] $Ni_{0.25}Co_{0.75}(OH)_2$ nanowire@nanoplatelet array	Ni foam	2 M KOH	-0.1-0.4 (SCE)	928.4	9.59	GS (5 mA/cm^2)	82-85 % (1000 cyc)	81.1 % (50 mA/cm^2)
[114] Co-Al LDHs Al_2O_3-CoO precursor	Pt plate	0.1 M NaOH	0-0.6 (Hg/HgO)	400 250	-	CV (5 mV/s)	-	-
[115] $Co^{II}Co^{III}$-CO_3 LDHs Co_2Al-CO_3 LDHs	Pt (0.07 cm^2)	0.1 M KOH	0-0.45 (SCE)	335 265	- -	GS (0.5 A/g)	- -	59.7 % (GS 5 A/g) 45.3 %
[116] Ni-Co LDH	Ni foam	1 M KOH	0-0.5 (SCE)	2682	-	GS (3 A/g)	-	63.6 % (GS 20 A/g)

Table 6. Summary of electrochemical performance of cobalt-based binary compounds and heterostructures.

Materials	Current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life	Rate capability
[117] (Co-Ni)$(OH)_2$.nH_2O	graphite	1 M NaOH	0.1-0.42 (Ag/AgCl)	700	0.301 [a]	GS (0.6 A/g)	-	-
[118] Ni-Co DH microspheres	Ni foam	6 M KOH	0-0.4 (SCE)	2275	-	GS (1 A/g)	92.9 % (5000 cyc)	44 % (GS 25A/g)
[119] Co_3O_4/$Ni(OH)_2$ $Co(OH)_2$/ $Ni(OH)_2$ $Ni(OH)_2$ Co_3O_4	Ti plate	1 M NaOH	0.04-0.52 (Ag/AgCl)	1144 823 113 161	0.342 [a] 0.412 [a] 0.057 [a] 0.081 [a]	CV (5 mV/s)	93.4 % 63.2 % - -	66 % (CV 100 mV/s) - -
[120] Co-Ni/Co-Ni oxides	stainless steel	1 M KOH	-0.7-0 (Ag/AgCl)	331	0.046 [a]	GS (1 A/g)	-	-
[121] $NiCo_2O_4$ aerogel	graphite	1 M NaOH	0.04-0.52 (Ag/AgCl)	1400	0.56 [a]	CV (25 mV/s)	91 % (2000 cyc)	-
[122] Co-Ni oxides (1:2) Co-Ni oxides (1:1) Co-Ni oxides (1:4) $Ni(OH)_2$/NiO Co_3O_4	Ni foam	1 M KOH	0-0.4 (SCE)	1539 1410 1060 1289 361	7.695 [a]	GS (1 A/g)	47 % (2000 cyc)	73.8 % (GS 5 A/g)
[123] $NiCo_2O_4$ (submicron) $NiCo_2O_4$ (nanoparticles) $NiCo_2O_4$ (coral-like)	Ni mesh	1 M KOH	0-0.45 (SCE)	217 188 103	1.215 [a] 1.053 [a] 0.577 [a]	GS (1 mA/cm^2)	96.3 % 85.1 % 83.5 % (600 cyc)	86.8 % (20 mA/cm^2) -
[124] Ni-Co oxide	Ni foam	6 M KOH	-0.1-0.4 (SCE)	286.9	-	GS (0.2 A/g)	-	-
[125] Ni-Co oxide porous nanoflakes	Ni foam	2 M KOH	0-0.55 (Hg/HgO)	867.3 [α]	-	GS (1 A/g)	93.5 %	92.3 % (GS 10 A/g)
				[α] 1550 after activation				
[126] $Co_{0.56}Ni_{0.44}$ oxide nanoflakes	Ni gauze	2 M KOH	0-0.4 (SCE)	1227	9.816 [a]	GS (0.625 A/g)	-	-
[127] $NiCo_2O_4$	Ni mesh	1 M NaOH	0-0.45 (SCE)	671	0.403 [a]	GS (1 A/g)	98 % (2500 cyc)	-
[128] $NiCo_2O_4$ mesoporous nanowires	graphite paper	1 M KOH	-0.05-0.45 (Ag/AgCl)	743	-	GS (1 A/g)	93.8 % (3000 cyc)	78.6 % (GS 40 A/g)
[129] $NiCo_2O_4$ (Ni/Co = 1) $NiCo_2O_4$ (Ni/Co = 2)	Ni foam	6 M KOH	0-0.5 (Hg/HgO)	722 760	0.722 0.760	GS (1 A/g)	80 % 81 % (3000 cyc)	79 % 70 %
[130] $NiCo_2O_4$	graphite paper	1 M KOH	-0.1-0.5	658	0.658 [a]	GS	98.43 %	80.5 %

Co_3O_4 NiO			(Ag/AgCl)	60 194	0.060 [a] 0.194 [a]	(1 A/g)	96.67 % 92.11 % (1000 cyc)	51.7 % 78.4 % (GS, 10 A/g)
[131]$Co(OH)_2/Ni(OH)_2$ (3:2) $Ni(OH)_2$ $Co(OH)_2$	Ni foam	1 M LiOH	-0.3-0.55 (SCE)	~270 ~380 ~100	- - -	GS (0.5 A)	88.2 % 41.6 % 47.4 % (1000 cyc)	- - -
[132]$NiCo_2O_4$ nanorods $NiCo_2O_4$ nanoflakes	ITO glass	2 M KOH	0-0.5 (Ag/AgCl)	490 330	0.147 [a] 0.099 [a]	CV (20 mV/s)	93 % (1000 cyc)	- -
[133]$NiCo_2O_4$ nanorods	stainless steel	1 M KOH	0-0.45 (Ag/AgCl)	456	0.137 [a]	CV (20 mV/s)	91 % (1000 cyc)	70 % (CV, 200 mV/s)
[134]Co-Ni hydroxides Co hydroxide Ni hydroxide	stainless steel	2 M KOH	0-0.4 (SCE)	672 354 425	- - -	CV (5 mV/s)	87 % 78 % 82 % (1000 cyc)	57.6 % (CV 100 mV/s) - -
[135]$NiCo_2O_4$ ultralayered mesoporous nanowires Co_3O_4 NiO	Ni foam	6 M KOH	-0.1-0.35 (SCE)	401 70 258	3.4	GS (1 A/g)	90 % (5000 cyc)	75.1 % (GS, 8 A/g)
[136]$NiCo_2O_4$ porous nanosheets	FTO glass	1 M KOH	0-0.5 (SCE)	506	-	GS (1 A/g)	94 % (2000 cyc)	40 % (GS, 10 A/g)
[137]$Co(OH)_2/Ni(OH)_2$ $Ni(OH)_2$	Ni foam	6 M KOH + 15g/L LiOH	0.1-0.56 (Hg/HgO)	2193 1914	5.483 [a] 4.785 [a]	GS (2 A/g)	84.7 % 69.1 % (1000 cyc)	63.3 % 45.7 % (GS, 20 A/g)
[138]$Ni_{0.37}Co_{0.63}(OH)_2$	glassy carbon	1 M NaOH + 0.5 M Na_2SO_4	0-1.5 (RHE)	1840	0.017 [a]	CV (1 mV/s)	99.2 % (500 cyc)	48.4 % (CV, 50 mV/s)
[139]$NiO/NiCo_2O_4/Co_3O_4$ composite	Ni foam	2 M KOH	0-0.4 (SCE)	1717	-	GS (5 mA/cm^2)	94.9 % (1000 cyc)	75.5 % (GS, 50 mA/cm^2)
[140]$NiCo_2O_4$ nanosheets	Ni foam	2 M KOH	0-0.45 (SCE)	2925	3.51	GS (1.8 mA/cm^2)	93.3 % (3000 cyc, 8.5 mA/cm^2) 83.1 % (3000 cyc, 25 mA/ cm^2)	58.4 % (GS, 19.8 mA/cm^2)
[141]$NiCo_2O_4$ nanotubes $NiCo_2O_4$ nanofibers $NiCo_2O_4$ nanobelts	Ni foam	2 M KOH	0-0.4 (Ag/AgCl)	1647.6 976.5 819.9	- - -	GS (1 A/g)	93.6 % (3000 cyc) - -	77.3 % (GS 25A/g) 48.0 % 50.8 %
[142]$NiCo_2O_4$ nanosheets	Ni foam	3 M KOH	-0.1-0.3	2010	1.608 [a]	GS (2 A/g)	94 %	72.1 %

			(SCE)				(2400 cyc)	(GS, 20 A/g)
[143]$NiCo_2O_4$ nanoneedles	Ni foam	2 M KOH	0-0.4 (SCE)	3466	3.12	GS (1.11 mA/cm^2)	89.3 % (2000 cyc)	25.3 % (GS, 11.12 mA/cm^2)
[142]$NiCo_2O_4$ nanoflakes-1 (molar ratio Co/Ni = 1) $NiCo_2O_4$ nanoflakes-2 (molar ratio Co/Ni = 2) Co_3O_4 NiO	Ni foam	2 M KOH	0-0.65 (Hg/HgO)	778.2 867.3 460.0 518.2	-	GS (1A/g)	-	84.1 % 92.3 % 79.0 % 94.7 % (GS, 10 A/g)
[144]$NiCo_2O_4$ chain-like nanowires	Ni foam	6 M KOH	0-0.45 (Ag/AgCl)	1284	-	GS (2 A/g)	97.5 % (3000 cyc)	76.8 % (GS 20 A/g)
[145]$NiCo_2O_4$ urchin-like nanostructures	Ni foam	3 M KOH	0-0.4 (SCE)	1650		GS (1 A/g)	81.8 % (2000 cyc)	81.7 % (GS 15 A/g)
[146]$NiCo_2O_4$ nanosheets	Ni foam	2 M KOH	0-0.55 (SCE)	1088	2.61	GS (5 mA/cm^2)	~100 % (1800 cyc)	78.5 % (GS 30 mA/cm^2)
[147]$NiCo_2O_4$ mesoporous nanosheets	Ni foam	2 M KOH	0-0.45 (SCE)	-	3.51	GS (1.8 mA/cm^2)	93.3 % (3000 cyc)	58.4 % (19.8 mA/cm^2) 39.0 % (48.6 mA/cm^2)
[148]$Co_{0.45}Ni_{0.55}O$/rGO	graphite paper	1 M KOH	0-0.5 (Ag/AgCl)	823	-	GS (1 A/g)	100 % (1000 cyc)	78.2 % (10 A/g)
[149]$ZnCo_2O_4$	stainless steel	6 M KOH	-0.1-0.3 (2-electrode)	77	-	CV (5 mV/s)	-	54.5 % (CV 50 mV/s)
[150]$ZnCo_2O_4$ aerogel	graphite	1 M NaOH	0.05-0.5 (Ag/AgCl)	700	0.35 [a]	CV (5 mV/s)	95 % (3000 cyc)	82.1 % (CV, 25 mV/s)
[151]Mn-Ni-Co oxide	Ni grid	6 M KOH	-0.1-0.4 (SCE)	1080	-	GS (5 mA)	~100 % (1000 cyc)	-
[152]$(Co,Mn)_3O_4$ nanowires	Ni foam	6 M KOH	0-0.37 (Ag/AgCl)	611.4	-	GS (2.38 A/g)	95 % (2000 cyc)	46.5 % (GS 23.8 A/g)
Nickel-cobalt sulfides								
[153]$NiCo_2S_4$ hollow nanoplates	Ni foam	3 M KOH	-0.1-0.4 (SCE)	437	0.010 [a]	GS (1 A/g)	81 % (1000 cyc)	53.2 % (GS 20 A/g)
[154]$NiCo_2S_4$ porous nanotubes	Ni foam	6 M KOH	-0.1-0.5 (Hg/HgO)	1093	-	GS (0.2 A/g)	63 % (1000 cyc)	73.2 % (GS 2 A/g) 50.3 % (GS 5 A/g)
[155]$NiCo_2S_4$ nanotubes	Ni foam	6 M KOH	0-0.55 (Hg/HgO)	2398	14.39	GS (5 mA/cm^2)	92 % (5000 cyc)	67.7 % (150 mA/cm^2)

$NiCo_2S_4$ hollow nanoprisms Ni_2CoS_4 hollow nanoprisms	Ni foam	2 M KOH	0-0.5 (SCE)	895 870	0.895 [a] 0.870 [a]	GS (1 A/g)	85.7 % (1500 cyc) 86.5 %	65.4 % (GS 20 A/g) 50.1 %
[156]$CoNi_2S_4$ nanoparticles	Ni foam	3 M KOH	0-0.4 (SCE)	1169	-	GS (1 A/g)	~100 % (2000 cyc)	60.1 % (5 A/g)
[157]Ni-Co sulfide nanowires	Ni foam	1 M KOH	0-0.45 (Ag/AgCl)	2415	6.0	GS (2.5 mA/cm^2)	78.5 % (3000 cyc)	48.7 % (30 mA/cm^2)
[158]$NiCo_2S_4$ nanotubes	Ni foam	6 M KOH	-0.1-0.4 (SCE)	738	3.10 [a]	GS (4 A/g)	93.4 % (4000 cyc)	78 % (32 A/g)
[159]$NiCo_2S_4$ urchin-like nanostructures	Ni foam	6 M KOH	0-0.565 (Hg/HgO)	1149	2.03-3.04 [a]	GS (1 A/g)	91.4 % (5000 cyc)	77.3 % (20 A/g) 66.2 % (50 A/g)
Heterostructures								
[160]Co_3O_4 nanowire@ MnO_2 nanosheets Co_3O_4 nanowire	stainless steel	1 M LiOH	-0.2-0.6 (Ag/AgCl)	480 -	0.71 ~0.22	GS (4 mA/cm^2)	97.3 % 82.6 % (1000 cyc)	56 % (GS, 44.7 mA/cm^2)
[161]CoO nanowire@ $Ni(OH)_2$ nanoflakes	Ni foam	1 M NaOH	0.01-0.52 (Ag/AgCl)	798.3	2.39 [a]	GS (1.67 A/g)	96.7 % (2000 cyc)	84 % (GS, 13.33 A/g)
[162]Co_3O_4 nanowire@ NiO nanoflakes Co_3O_4 nanowire arrays NiO nanoflakes arrays	Ni foam	2 M KOH	0-0.6 (Hg/HgO)	853 642 178	2.56 [#] 1.36 [#] 0.16 [#]	GS (2 A/g)	95.1 % 85.5 % 56.7 % (6000 cyc)	85 % 76.7 % 66.6 % (GS, 40 A/g)
[#] capacitance values after 6000 cycles								
[163]CoO porous nanowalls@$Ni(OH)_2$ nanowalls	Ni foam	1 M NaOH	0-0.55 (Ag/AgCl)	2374.0 539.8	11.49 2.32	GS (5 mA/cm^2) GS (1.17 A/g)	68.9 % (5000 cyc) ~95 % (5000 cyc)	56.5 % (40 mA/cm^2) 67.5 % (9.30 A/g)
[164]Co_3O_4@$Co(OH)_2$ nanowire arrays	Ni foam	2 M KOH	0-0.4 (Hg/HgO)	1095	1.64 [a]	GS (1 A/g)	92 % (2000 cyc)	74.2 % (40 A/g)
[165]Co_3O_4 nanosheets@Ni-Co oxide nanorods Co_3O_4 nanosheets	Ni foam	1 M KOH	0-0.45 (SCE)	2098 390	24.95 2.48	GS (5 mA/cm^2)	96 % (1000 cyc) -	73 % (30 mA/cm^2) 57.9% (30 mA/cm^2)
[166]ITO nanowire@ $Co(OH)_2$ nanoflake $Co(OH)_2$ nanoflake	stainless steel	1 M KOH	-0.15-0.35 (Ag/AgCl)	622 585	0.20 [a] 0.22 [a]	CV (5 mV/s)	-	72.3 % 33.3 % (CV, 100 mV/s)

[167]Zn_2SnO_4 nanowires@NiCo LDH	stainless steel	2 M KOH	-0.1-0.3 (SCE)	1805	-	GS (0.5 A/g)	-	74.2 % (GS 80 A/g)
[168] $MnMoO_4$ nanowire@ $CoMoO_4$ nanowire $MnMoO_4$ nanowire $CoMoO_4$ nanowire $MnMoO_4$/$CoMoO_4$ composite	Ni foam	2 M KOH	-0.6-0.4 (Ag/AgCl)	204.1 187.1 9.7 62.8 69.2	- - 	GS (0.5 A/g) GS (1 A/g) GS (1 A/g)	98 % (1000 cyc)	66.0 % (GS, 3 A/g)
[169]$NiCo_2S_4$ nanorods $NiCo_2S_4$ nanotubes $Co_xNi_{1-x}(OH)_2$/$NiCo_2S_4$ nanotubes	carbon fiber paper	1 M KOH	0-0.5 (Hg/HgO)	-	0.52 0.87 2.86	GS (4 mA/cm^2)	- - 96 % (2000 cyc)	76.9 % 66.7 % 84.3 % (20 mA/cm^2)
[170]CoAl LDH@PEDOT core/shell nanoplatelets CoAl LDH nanoplatelets	Ni foil	6 M KOH	-0.1-0.55 (Hg/HgO)	672 584	- -	GS (1 A/g)	92.5 % 32 % (5000 cycles)	63.1 % 29.5 % (CV, 40 A/g)
[171]CoO nanowires PPy on CoO nanowires	Ni foam	3 M NaOH	-0.2-0.45 (Ag/AgCl)	1212 2223	1.23 4.43	GS (1 mA/cm^2)	99.8 % (2000 cyc)	48 % (10 mA/cm^2)
[172]Co_3O_4@PPy@MnO_2 core-shell-shell nnaowires Co_3O_4@PPy core-shell nanowires Co_3O_4 nanowires	Ni foam	1 M NaOH	-0.2-0.6 (Hg/HgO)	627 - -	1.13 0.58 0.36	GS (1.2 mA/cm^2)	-	-
[173]Ni-Co oxide nanowires/TiO_2 nanotubes	Ti foil	1 M NaOH	0-0.5 (Ag/AgCl)	2353	-	GS (2.5 A/g)	95.2 % (3000 cyc)	92.3 % (GS 50 A/g)
[174]$Ni_xCo_{2x}(OH)_{6x}$/TiN nanotubes $Ni(OH)_2$/TiN nanotubes $Co(OH)_2$/TiN nanotubes	Ti foil	0.1 M KOH + 1.9 M KCl	-0.05-0.45 (SCE)	2543 2400 1400	0.27 - -	CV (5 mV/s)	93.75 % (5000 cyc) - -	65.5 % (CV 100 mV/s) 33.3 % 57.1 %
[175]MoO_2 thin film/$Co(OH)_2$ nanoflakes MoO_2 thin film $Co(OH)_2$ nanoflakes	Ni foam	2 M KOH	-0.2-0.45 (SCE)	1697 - -	-	GS (2 A/g)	97 % (5000 cyc, 20 A/g) 47 % 39 %	39 % (40 A/g) 28 % 30 %
[176]NiO/Co_3O_4 mesoporous nanosheets (Ni:Co=4:1) NiO/Co_3O_4 mesoporous nanosheets (Ni:Co=3:2)	Ni foam	1 M KOH	0-0.4 (Ag/AgCl)	992 1190	-	GS (4 A/g)	92.3 % (5000 cyc) 99.1 %	81 % (GS 20 A/g) 67 %

NiO mesoporous nanosheets				960			97.5 %	66 %
^{177}Mo-decorated Co_3O_4 nanowires Co_3O_4 nanowires	Ni foam	2 M KOH	0-0.43 (SCE)	2000 1257	4.54 2.11	GS (1.7 mA/cm^2)	53 % (2000 cyc) 84 %	46.3 % (GS 85 mA/cm^2) 5.8 %

Table 7. Summary of electrochemical performance of various cobalt compounds-carbon nanomaterials composites.

Materials	Current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life (cycling no.)	Rate capability
Composites of cobalt compounds-one dimensional carbon nanomaterials								
[178](Ni/Co)O_x-CNTs film	Ni mesh	1 M KOH	0-0.45 (SCE)	1024	1.956 [a]	GS (2 mA/cm^2)	93.0 % (1000 cyc)	82 % (GS, 10 mA/cm^2)
[179]Co-Al LDH-MWCNTs	Ni foam	1 M KOH	0-0.5	342.4	3.424 [a]	GS	88.8 % (200)	-
Co-Al LDH			(SCE)	192	1.920 [a]	(2 A/g)	-	-
[180](Ni/Co)O_x-CNTs film	graphite	1 M KOH	0-0.5 (SCE)	569	0.176 [a]	GS (10 mA/cm^2)	96.4 % (2000 cyc)	95.4 % (GS, 100 mA/cm^2)
[181]CNTs	*alumina*	0.5 M H_2SO_4	0-1	-	6.3	CV	-	-
$Co(OH)_2$-CNTs	*(as support)*		(Ag/AgCl)	-	12.74	(100 mV/s)		
[182]CoOOH-CNTs	ITO glass	0.1 M Na_2SO_4	0.1-0.9	389	-	GS	-	-
CoOOH			(Ag/AgCl)	209		(10 μA/cm^2)		
[183]Co_3O_4-CNTs sheet	-	1 M KOH	0-0.5 (SCE)	302	-	CV (10 mV/s)	-	~50 % (GS, 155 A/g)
[184]$NiCo_2O_4$-SWCNTs	Ni foam	2 M KOH	-0.05-0.4 (Ag/AgCl)	1642	4.926 [a]	GS (0.5 A/g)	94.1 % (2000 cyc)	53.5 % (GS, 20 A/g)
[185](Co/Ni)O_x	Ni foam	1 M KOH	0-0.5	936	0.721 [a]	CV	-	65.4 %
(Co/Ni)O_x-carbon fibers			(Ag/AgCl)	1271	0.979 [a]	(5 mV/s)		75.1 % (CV, 100 mV/s)
[186]$CoMnO_2$				419	-		-	67.5 %
$CoMnO_2$-carbon fibers				630			95 % (10000 cyc)	54.3 % (CV, 100 mV/s)
[187]Co_3O_4 nanocrystals-1D nanoporous carbon	(not available)	1 M KOH	0-0.6 (SCE)	382	-	GS (3 A/g)	-	81.0 % (GS, 30 A/g) 72.8 % (GS, 60 A/g)
[188]CNF	Ni foam	6 M KOH	-1-0	127	0.381 [a]	GS	-	-
$Co(OH)_2$-CNF			(SCE)	157	0.471 [a]	(1 A/g)		86 % (GS, 5 A/g)
$Co(OH)_2$			-0.2-0.35	100			-	-
$Co(OH)_2$-CNF			(SCE)	322 *				64.0 % (GS, 5 A/g)
				***** based on weight of $Co(OH)_2$ phase				
[189]Co_3O_4	Ni gauze	2 M KOH	-0.2-0.4	263	-	GS	-	59 %
MWCNTs			(SCE)	95		(0.625 A/g)	-	75 %
Co_3O_4-5%MWCNTs				418			91 % (2000 cyc)	70 % (GS, 6.25 A/g)

[190]CoS_x-FMWCNTs	Ni foam	2 M KOH	-0.3-0.45 (SCE)	334	-	GS (0.4 A/g)	95 % (1000 cyc)	89.8 % (GS, 3 A/g)
[191]CoS-CNTs	FTO substrate	1 M KOH	-	-	-	-	-	-
[192]$CoMoO_4$-MWCNTs	glassy carbon disc	1 M KOH	-0.55-0.25 (Hg/HgO)	170	-	GS (0.1 A/g)	93.2 % (1000 cyc)	56.5 % (GS, 1 A/g)
[193]Ni-Co hydroxide-MWCNTs (15 wt %)	stainless steel	1M KOH	-0.6-0.4 (Ag/AgCl)	502	-	CV (5 mV/s)	83 % (5000 cyc)	55.0 % (CV, 100 mV/s)
[194]$NiCo_2O_4$ nanorods-carbon nanofibers $NiCo_2O_4$ ultrathin nanosheets-carbon nanofibers	Ni foam	2 M KOH	0-0.45 (SCE) 0.1-0.55	1023.6 1002	- -	GS (1 A/g) GS (1 A/g)	91.5 % (2000 cyc) 96.4 % (2400 cyc)	48.8 % (GS 20 A/g) 51.9 % (GS 20 A/g)
[195]NiCoAl LDH-MWCNT NiCoAl LDH	Ni foam	6 M KOH	0-0.48 (Hg/HgO)	1035 950	-	GS (1 A/g)	83 % (1000 cyc) 78.3	57.7 % (GS 10 A/g) 24.4 %
[196]$C_xNi_{1-x}(OH)_2$ NSs-HCNA $(C_xNi_{1-x})_9S_8$ NSs-HCNA (HCNA: hollow carbon nanorod array; NS: nanosheets)	carbon fiber paper	1 M KOH	0-0.5 (Hg/HgO)		0.88 1.32	GS (1 mA/cm^2)	~88.5 % ~111.2 % (3000 cyc)	59.9 % 71.8 % (10 mA/cm^2)
Composites of cobalt compounds-two dimensional carbon nanomaterials								
[197]$Co(OH)_2$ rGO $Co(OH)_2$-rGO	Ni foam	6 M KOH	-0.2-0.5 (SCE)	726.1 137.6 972.5	-	GS (0.5 A/g)	-	-
[198]$Co(OH)_2$-vertically aligned graphene sheets	Ni foam	1 M KOH	-0.1-0.45 (SCE)	693.8	-	GS (2 A/g)	91.9 % (3000 cyc)	73.0 % (GS, 32 A/g)
[199]$Co(OH)_2$-rGO	Ni foam	2 M KOH	-0.1-0.4 (Ag/AgCl)	473	-	GS (1 A/g)	90 % (1000 cyc)	63.3 % (GS 10 A/g)
[200]rGO Co_3O_4-rGO	Ni foam	6 M KOH	0-0.4 (SCE)	169.3 243.2	-	CV (10 mV/s)	95.6 % (2000 cyc)	- 71.9 % (CV, 100 mV/s)
[201]rGO Co_3O_4 Co_3O_4-rGO	Pt foil	2 M KOH	-0.25-0.55 (SCE)	245 118 478	-	CV (5 mV/s)	-	-
[202]Co_3O_4 nanoscrolls Co_3O_4 nanoscrolls-rGO	glassy carbon electrode	6 M KOH	0-0.5 (Ag/AgCl)	14.9 159.8	0.015 [a] 0.160 [a]	CV (5 mV/s)	91 % 93 % (1000 cyc)	81.9 % 81.8 % (CV, 100 mV/s)
[203]rGO Co_3O_4	Ni foam	6 M KOH	-0.4-0.55 (Hg/HgO)	56 161	0.168 [a] 0.483 [a]	GS (1 A/g)	- -	- -

Co_3O_4-rGO				291	0.873 [a]		90 % (1000 cyc)	80 % (GS, 8 A/g)
[204]Co_3O_4-rGO	stainless steel	1 M NaOH	-0.2-0.5 (Ag/AgCl)	687	~0.48 [a]	CV (5 mV/s)	93.1 % (1000 cyc)	84.4 %
[205]Co_3O_4-rGO	Ni disk	2 M KOH	0-0.85 (2-electrode)	472		CV (2 mV/s)	95.6 % (1000 cyc)	82.6 % (CV, 100 mV/s)
[206]Co_3O_4/carbon core-branch nanowires	Ni foam	2 M KOH	0-0.55 (Hg/HgO)	700	1.19 [a]	GS (2 A/g)	94 % (5000 cyc)	82.3 % (GS 36 A/g)
[207]Co_3O_4/rGO	Ni foam	6 M KOH	-0.1-0.45 (SCE)	240	0.53 [a]	CV (5 mV/s)	95.8 % (1000 cyc)	-
[208]CoS_2-rGO rGO CoS_2	Pt foil	6 M KOH	-0.6-0.4 (SCE)	253 148 102	-	CV (5 mV/s)	-	58.5 % 67.6 % 62.7 % (50 mV/s)
[209]Co_3S_4 hollow nanospheres-rGO Co_3S_4 hollow nanospheres	Ni foam	2 M KOH	0-0.5 (Hg/HgO)	675.9 522.4	- -	GS (0.5 A/g)	90.4 % 54.5 % (1000 cyc)	77.2 % 66.0 % (GS, 5 A/g)
[210]$Co_{0.5}Ni_{0.5}(OH)_2$ nanodiscs-rGO-CNT	free standing film on Ni mesh	2 M KOH	-0.15-0.40 (SCE)	2360	-	GS (0.5 A/g)	75 % (5000 cyc)	86 % (GS 20 A/g)
[211]Co-Al LDH nanosheets (NS)-GO [212]Co-Al LDH NS-GO Co-Al LDH NS-rGO	Ni foam ITO	1 M KOH 1 MKOH	0-0.45 (Ag/AgCl) ~-0.2-0.5 (Ag/AgCl)	1031 880 1204	1.031 [a] 0.007 0.009	GS (1 A/g) CV (5 mV/s)	~100 % (6000 cyc) - -	46.8 % (GS, 8 A/g) 52.4 % 48.6 % (CV, 100 mV/s)
[213]$Co_{0.7}$-$Al_{0.3}$ LDHs-GO $Co_{0.7}$-$Al_{0.3}$ LDHs	Ni foam	6 M KOH	0-0.5 (HgO)	1137 560	- -	GS (1 A/g)	88 % (500) -	-
[214]Co-Al LDH-rGO	Ni foam	6 M KOH	0-0.5 (SCE)	711.5	3.558 [a]	GS (1 A/g)	81.2 % (2000 cyc)	72.6 % (GS, 10 A/g)
[215]Co-Al LDH (micro) Co-Al LDH (nano) rGO/Co-Al LDH (micro) rGO/Co-Al LDH (nano)	Ni foam	1 M KOH	0-0.5 (SCE)	466.5 360.7 581.6 484.8	-	GS (2 A/g)	-	-
[216]CoAl LDH/GO	Ni foam	6 M KOH	-0.1-0.35 (SCE)	772	-	GS (1 A/g)	73 % (5000 cyc)	80 % (GS 20 A/g)
[217]$NiCo_2O_4$-rGO $NiCo_2O_4$-rGO (physical mixed) $NiCo_2O_4$	Ni foam	6 M KOH	0.1-0.5 (Hg/HgO)	835 376 662	1.67 [a] 0.752 [a] 1.324 [a]	GS (1 A/g)	109 % (4000 cyc)) - 52 % (300 cyc)	73.7 % (GS 20 A/g) 65.7 % (GS 14 A/g) 52.7 % (GS 16 A/g)

[218]$NiCo_2O_4$ nanocrystals-rGO	Ni foam	2 M KOH	0.05-0.45 (Ag/AgCl)	1200	-	GS (0.5 A/g)	62.8 %	62.8 % (GS 40 A/g)
[219]$Ni(OH)_2$/CoO/rGO $Ni(OH)_2$/CoO $Ni(OH)_2$/ rGO	Ni foam	1 M NaOH	-0.05-0.55 (Hg/HgO)	1510	-	CV (1 mV/s)	84.8 % 63.4 % 70.2 % (2000 cyc)	43.0 % (CV 20 mV/s)
[220]Co_3O_4 microsphere arrays-rGO/CNTs	(PTFE membrane)	3 M KOH	-0.2-0.45 (SCE)	378	-	GS (2 A/g)	96 % (3000 cyc)	78.6 % (GS 8 A/g)
[221]$NiCo_2S_4$-rGO	Ni foam	2 M KOH	0-0.5 (Ag/AgCl)	1451	-	GS (3 A/g)	95.5 % (2000 cyc)	52.4 % (GS 20 A/g)
Composites of cobalt compounds-three dimensional carbon nanomaterials								
[222]$Co(OH)_2$-CMK-3	Ni foam	2 M KOH	-0.2-0.4 (SCE)	750	3.75 [a]	GS (5 mA/cm^2)	83 % (1000 cyc)	86 % (GS, 50 mA/cm^2)
[223]FDU16-800 (OMK) Co_3O_4 (10 %)-FDU16 Co_3O_4 (20 %)-FDU16	Mo-sputtered Si	1 M Na_2SO_4	-1 to -0.4 (Hg/Hg_2SO_4)	22 116 125	-	CV (5 mV/s)	-	-
[224]MCF Co-MCF	Ni foam	7 M KOH	-0.8-0	97.9 102	-	CV (5 mV/s)	-	54.9 % 81.4 % (CV 50 mV/s)
[225]$NiCo_2O_4$-carbon aerogel	graphite	1 M NaOH	-0.1-0.55 (Ag/AgCl)	1695	-	CV (25 mV/s)	97.6 % (2000 cyc)	~50 % (CV 500 mV/s)
[226]Co_3O_4 nanoclusters- SBA-15 supported carbon nanomembrane	-Ni foam	6 M KOH	-0.1-0.6 (Hg/HgO)	1086	-	CV (10 mV/s)	90 % (10000 cyc)	36.8 % (CV 200 mV/s)

Table 8. Summary of electrochemical performance of cobalt compounds synthesized on different 3D supports/ current collectors.

Materials	3D support/ current collector	Electrolyte	Potential window (V)	C_m (F/g)	C_a (F/cm^2)	Method	Cycle life	Rate capability
[227] Co_3O_4 Co_3O_4	porous Ni film flat Ni foil	1 M KOH	0-0.45 (SCE)	2200 209	-	CV (10 mV/s)	- 	94 % 59 % (CV 50 mV/s to 5 mV/s)
[228] $Co(OH)_2$	porous Ni film flat Ni foil	1 M KOH	-0.2-0.45 (SCE)	2800 550	0.07 [a] 0.014 [a]	CV (5 mV/s)	~100 % 75 %	96 % (CV 200 mV/s to CV 5 mV/s)
[229] $Co(OH)_2$ (Co-Ni mixed hydroxide)	porous Ni film	1 M KOH	-0.2-0.45 (SCE)	1665	0.12 [a]	CV (5 mV/s)	-	86 % (CV, 200 mV/s)
[230] α-$Co(OH)_2$ nanoflakes	Ni foam porous Ni film	2 M KOH	-0.1-0.6 (Hg/HgO)	880 2028	0.88 2	GS (2 A/g)	73.6 % 94.7 % (2000 cyc)	82.6 % 95 % (GS, 40 A/g)
[231] α-$Co(OH)_2$ nanoflakes α-$Co(OH)_2$/Ni nanoflakes	Ni foam	2 M KOH	0-0.4 (Hg/HgO)	1017 1310	~1.5 [a] ~2	GS (1 A/g)	76.7 % 93.7 % (2000 cyc)	76.4 % 87.6 % (GS, 40 A/g)
[232] α-$Co(OH)_2$ nanorods & nanoflakes	Ni coated-Si microchannel plates	2 M KOH	-0.1-0.6 (SCE)	-	1.46	CV (10 mV/s)	80.6 %	-
[233] $Co(OH)_2$ nanoflakes-nanoparticles	Ni coated-Si microchannel plates	2 M KOH	-0.1-0.4 (SCE)	-	6.90	GS (10 mA/cm^2)	87.4 % (1000 cyc)	93.8 % (GS 80 mA/cm^2)
[234] Ni-Co oxides nanowires	TiO_2 NTs-Ti foil	1 M NaOH	0-0.5 (Ag/AgCl) 0-0.5 (2-electrode)	2353 187	0.941 [a] -	GS (2.5 A/g) GS (1 A/g)	95.2 % (3000 cyc) 93.7 % (1000 cyc)	92.4 % (GS, 50 A/g) -
[235] Co_3O_4 nanowire network	carbon fiber paper	2 M KOH	0-0.8 (2-electrode)	948	0.476 [a]	GS (0.25 A/g)	100 % (5000 cyc)	94.4 % (GS, 25.34 A/g)
[236] $NiCo_2O_4$ nanowires $Co_{0.33}Ni_{0.67}$DHs nanosheets/$NiCo_2O_4$ nanowires $Co_{0.5}Ni_{0.5}$DHs nanosheets/$NiCo_2O_4$ nanowires $Co_{0.67}Ni_{0.33}$DHs nanosheets/$NiCo_2O_4$ nanowires	carbon fiber paper	1 M KOH	-0.25 to 0.55 (3-electrode)	- >2000 >2250 >1500	0.41 1.88 2.17 1.52	GS (10 A/cm^2)	- 68 % (2000 cyc) 72 % (2000 cyc) 81 % (2000 cyc)	- 51.9 % (150 A/cm^2) 60.8 % (150 A/cm^2) 53.0 % (150 A/cm^2)
[237] Co_3O_4 nanowires	carbon fiber paper planar carbon paper	30 wt % KOH	-0.2-0.6 (Ag/AgCl)	1525 1199	-	GS (1 A/g)	-	-

	carbon fiber paper planar carbon paper		0-0.8 (2-electrode)	911 620	-	GS (0.25 A/g)	94 % 91 % (5000 cyc)	87 % 71 % (GS, 25 A/g)
[238]MnO_2 nanowires CoAl LDH MnO_2 nanowires-CoAl LDH	flexible carbon fibers	1 M LiOH	-0.2-0.6 (Hg/HgO)	118 442 944	-	GS (1 A/g)	- 93.4 % 98.2 %	10.1 49.8 64.6 (GS, 20 A/g)
[239]$NiCo_2O_4$ nanowires	carbon textiles	6 M KOH	–0.05 to 0.45 (SCE)	1283	-	GS (1 A/g)	~100 % (5000 cyc)	79 % (20 A/g)
[240]CoO nanocubes	porous carbon skeleton	2 M KOH	0-0.45 (SCE)	1438	-	GS (2 A/g)	82 % (3000 cyc)	54.8 % (20 A/g)
[241]$Co(OH)^2$	MWCNTs-cotton fibers	3 M KOH	-0.3-0.45 (SCE)	-	11.22	GS (15 mA/cm^2)	96 % (2000 cyc)	68.7 % (GS, 60 mA/cm^2)
[242]Co_3O_4 nanowires	graphene foam	2 M KOH	0-0.5 (Ag/AgCl)	768	-	GS (10 A/g)	100 % [b] (1000 cyc)	59 % (GS, 30 A/g)
[243]$Co(OH)_2$ nanowhiskers	ultra-stable zeolite Y	2 M KOH	-0.15-0.45 (SCE)	1492	14.92	GS (4 mA/cm^2)	96 % (6000 cyc)	-
[244]$Co(OH)_2$-$Ni(OH)_2$	ultra-stable zeolite Y	1 M KOH	-0.1-0.45 (SCE)	479	4.79	GS (2 mA/cm^2)	96 % (600 cyc)	-
[245]$Co(OH)_2$/SBA-15(10 %) $Co(OH)_2$/SBA-15 (20 %)	mesoporous silica SBA-15	2 M KOH	-0.2-0.4 (SCE)	467.5 417.5	-	GS (5 mA/cm^2)	-	87.2 % 92.3 % (GS, 30 mA/cm_2)

Table 9. Asymmetric ECs and other types of EC devices involved cobalt compounds/ composites.

Positive electrode	Negative electrode	Electrolyte	Potential window (V)	C_m/ (F/g)	Method	Rate capability	Cycle life	Energy density (Wh/kg)	Power density (W/kg)
[22] Co_3O_4/C core-shell nanowires Co_3O_4 nanowires	activated carbon	2 M KOH	-	-	-	-	92 % (8000 cyc) 88 %	21.5 14.7	4500 4500
[82] $Co(OH)_2$ nanorods	GO	1 M KOH	0-1.2	59	GS (6.6 A/g)	-	-	11.9	2540
[246] $Co(OH)_2$/USY composite	activated carbon	1 M KOH	0-1.5	110	GS (2 mA/cm^2)	89.1 % (25 mA/cm^2)	77 % (500 cyc)	30.6	520.8
[247] $Co(OH)_2$ nanoflakes	activated carbon	2 M KOH	0-1.6	72.4	GS (5 mA/cm^2)	78.5 % (50 mA/cm^2)	93.2 % (1000 cyc)	72.7	2395.2
[248] $Co_{0.56}Ni_{0.44}$ oxide nanoflakes	activated carbon	2 M KOH	0-1.6	97	GS (166.7 mA/g)	65.2 % (1666.7 mA/g)	83 % (1000 cyc)	34.5	133.3
[249] $NiCo_2O_4$-graphene	activated carbon	6 M KOH	0-1.4	288	GS (0.5 A/g)	60 % (30 A/g)	~102 % (10000 cyc)	7.57	5600
[250] CoAl LDH CoAl LDH/rGO	activated carbon activated carbon	6 M KOH	0-1.75	~65 ~87	CV (5 mV/s)	~43 % ~66 % (80 mV/s)	82 % 90 % (6000 cyc)	25.1 35.5	875 875
[116] Ni-Co LDH	rGO	1 M KOH	0-1.6	-	-	-	82 % (5000 cyc)	188 141 105 78.5 61.2 21.8	1499 2797 3927 4881 5593 7324
[210] $Co_{0.5}Ni_{0.5}(OH)_2$ nanodiscs-rGO-CNT	activated carbon-few-wall CNTs	2 M KOH	0-1.4	150	GS (0.3 A/g)	70.7 % (GS 6 A/g)	-	41 29	210 4200
[251] $NiCo_2O_4$ nanowires-Ni foam	$NiCo_2O_4$ nanowires-Ni foam	PVA-KOH gel (solid)	0-1	0.16 F/cm^2	GS (1 mA/cm^2)	~86 % (8 mA/cm^2)	100 % (3000 cyc)	-	-
[157] Ni-Co sulfide nanowires	activated carbon	1 M KOH	0-1.8	-	GS (8 mA/cm^2)	-	73.1 % (3000 cyc)	25 17.8	447 3570
[252] Co_9S_8 nanorods	Co_3O_4@RuO_2 nanosheet arrays	3 M KOH PVA/KOH gel (solid)	0-1.6 0-1.6	3.42 F/cm^3 4.28 F/cm^3	GS (2.5 mA/cm^2)	-	99.0 % (2000 cyc) 90.2% (2000 cyc)	1.21 mWh/cm^3 1.44 mWh/cm^3	13.29 W/cm^3 0.89 W/cm^3
[148] $Co_{0.45}Ni_{0.55}O$/rGO	rGO	1 M KOH	0-1.5	113	GS (0.5 A/g)	~88% (5A/g)	96 % (1000 cyc)	35.3 28.0	- 3614.0
[167] Zn_2SnO_4 nanowires@NiCo	activated carbon	2 M KOH	0-1.2	118.4	CV (5 mV/s)	54.4 % (100 mV/s)	92.7 % (5000 cyc)	23.7 9.7	284.2 5817.2

LDH						40.9 % (200 mV/s)			
[171]CoO nanowires PPy on CoO nanowires	activated carbon	3 M NaOH	0-1.8	~102	GS (1 mA/cm^2)	~70 %(100 mA/cm^2)	91.5 % (20000 cyc)	43.5 11.8	87.5 5500
[172]Co_3O_4@PPy@MnO_2 core-shell-shell nnaowires Co_3O_4@PPy core-shell nanowires Co_3O_4 nanowires	activated carbon	1 M NaOH	0-1.6	-	-	-	~104 % (11000 cyc)	34.3 5.6	80.0 12000

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