Supplementary Material

Biomass Chitosan Derived Cobalt/Nitrogen Doped Carbon Nanotube for Electrocatalytic Oxygen Reduction Reaction

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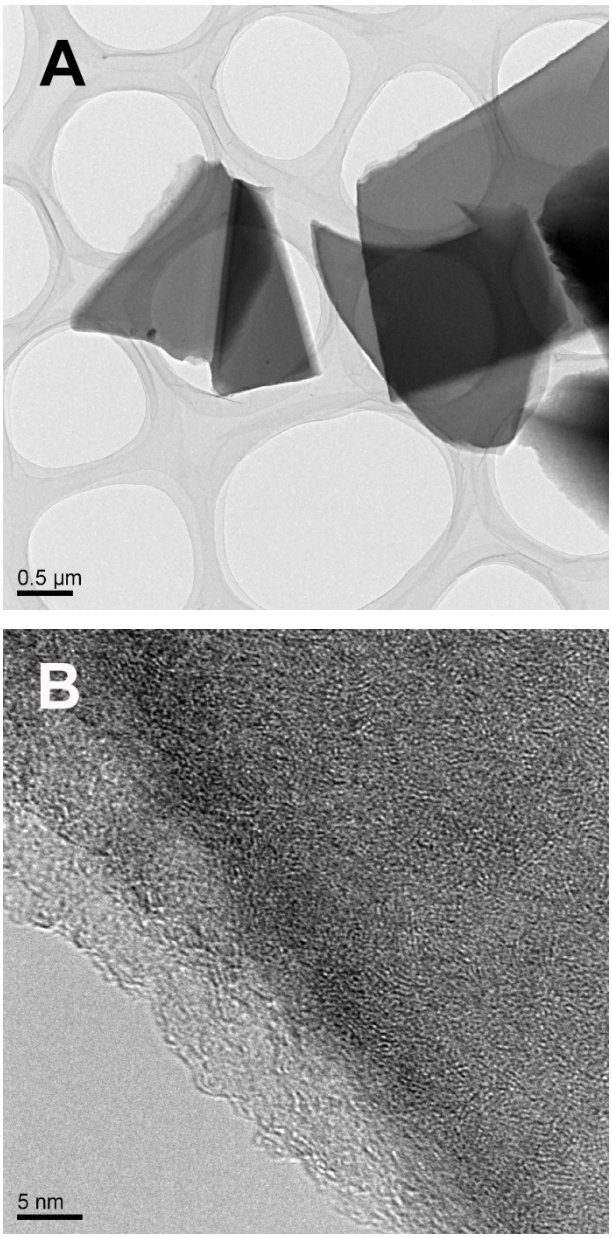

Figure S1. TEM images for CNS-T800.

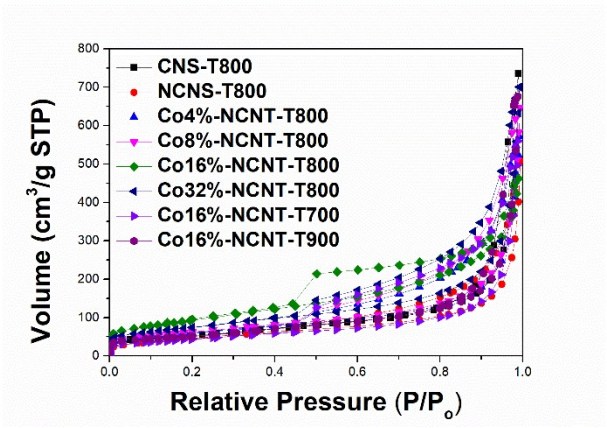

Figure S2. N_2 sorption isotherms of samples. The calculated BET specific surface area are 73, 176, 221, 223, 337, 266, 159 and 183 $m^2 \cdot g^{-1}$ for CNS-T800, NCNS-T800, Co4%-NCNT-T800, Co4%-NCNT-T800, Co4%-NCNT-T800, Co4%-NCNT-T800, Co4%-NCNT-T800 Co4%-NCNT-T800 respectively.

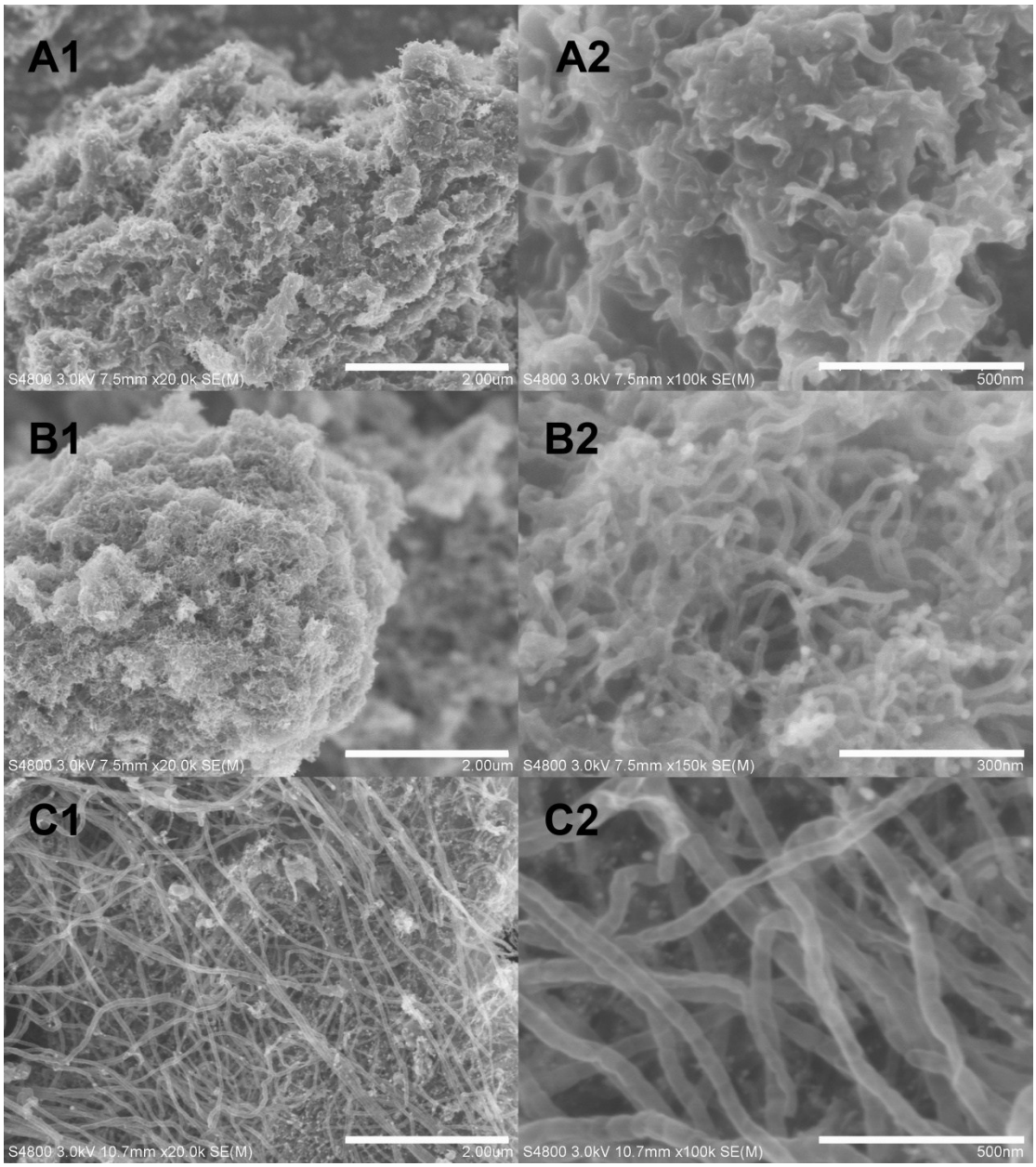

Figure S3. SEM images of (A1) scale bar 2 um and (A2) scale bar 500 nm for Co8%-NCNT-800, (B1) scale bar 2 um and (B2) scale bar 300 nm for Co16%-NCNT-800 and (C1) scale bar 2 um and (C2) scale bar 500 nm for Co32%-NCNT-800. It can be seen from A1 and A2 that there are still preserved some nanosheet morphology of Co8%-NCNT-800. B1 and B2 have shown uniform CNTs with diameter less than 30 nm of Co16%-NCNT-800 while C1 and C2 have shown increased diameter of CNTs over 50 nm for Co32%-NCNT-800.

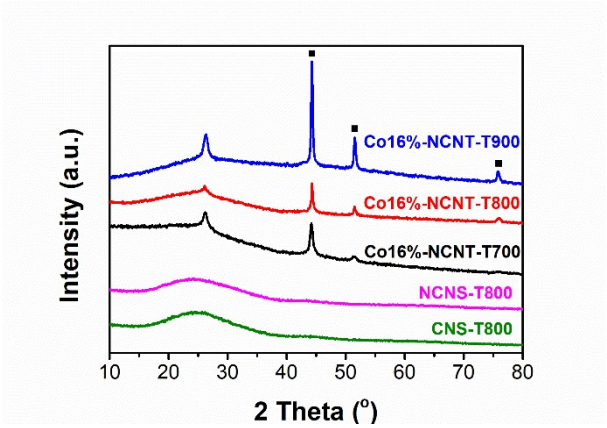

Figure S4. XRD patterns of Co16%-NCNT-T700, Co16%-NCNT-T800 and Co16%-NCNT-T900. The peak centered at 26.29° should be attributed to 002 facet of graphitic layers while the peaks (O) attributed to metallic Co (PDF#15-0806)

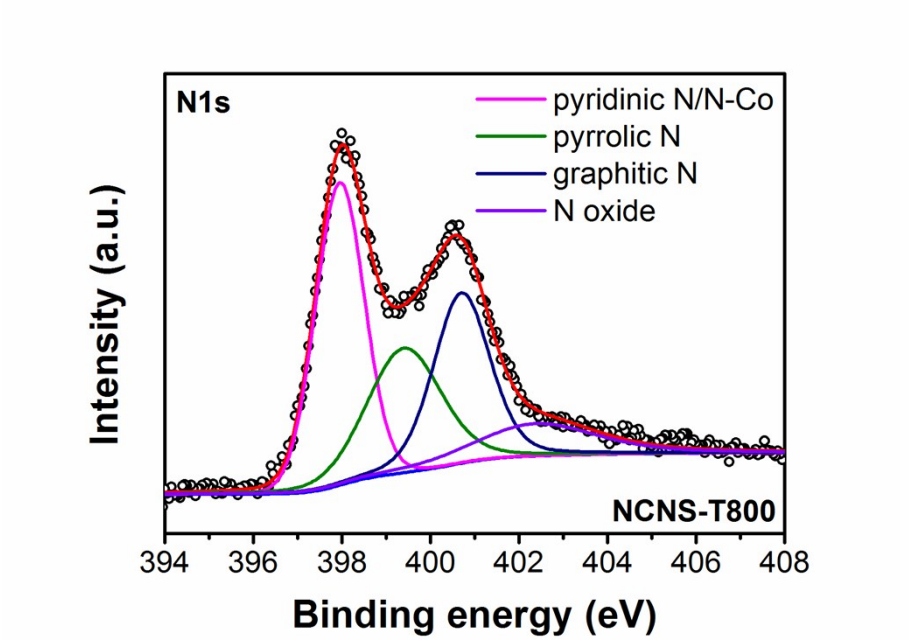

Figure S5. Deconvoluted N1s spectrums for NCNS-T800.

Table S1. XPS elemental analysis of Co16%-NCNT-T700, Co16%-NCNT-T800, Co16%-NCNT-T900, NCNS-T800 and CNS-T800 samples.

Samples	Co16%-NCNT-T700	Co16%-NCNT-T800	Co16%-NCNT-T900	NCNS-T800	CNS-T800
C (at%)	86.06	88.19	94.28	85.41	89.74
O (at%)	3.17	2.73	2.13	4.3	10.26
N (at%)	9.11	7.61	2.20	10.29	N/A
Co(at%)	1.66	1.47	1.39	N/A	N/A
Pyri-N/N (%)	49.69	37.36	35.22	37.51	N/A
Pyrro-N/N (%)	20.78	14.55	11.57	24.88	N/A
Graph-N/N (%)	15.9	35.59	35.90	26.41	N/A
N oxide/N (%)	13.63	12.5	17.31	11.2	N/A

Table S2. Comparison of our catalyst with recently reported catalysts

Catalysts	Electrolyte	$E_{1/2}$ (V vs. RHE)	limiting current density(mA cm^{-2})	Reference
Co16%-NCNT-T800	0.1 M KOH	0.835	6.92	This work
C-Fe-Z8-Ar	0.1M $HClO_4$	0.82	7.4	1
Fe−N−CC	0.1 M KOH	0.83	4.6	2
Fe−N/C-800	0.1 M KOH	0.809	6.06	3
Co SAs/N-C(900)	0.1 M KOH	0.881	5.6	4
N/Co-dopedPCP//NRGO	0.1 M KOH	0.86	7.5	5
CoCN@CoO_x(18)/NG	0.1 M KOH	~0.83	5.86	6
Co_xS_y@C-1000	0.1 M KOH	~0.83	4.6	7
CoO_x /Co@GC-NC-0	0.1 M KOH	0.822	5.5	8
MOFs-800	0.1 M KOH	0.8	3.85	9
CoP	0.1 M KOH	0.7	4.5	10

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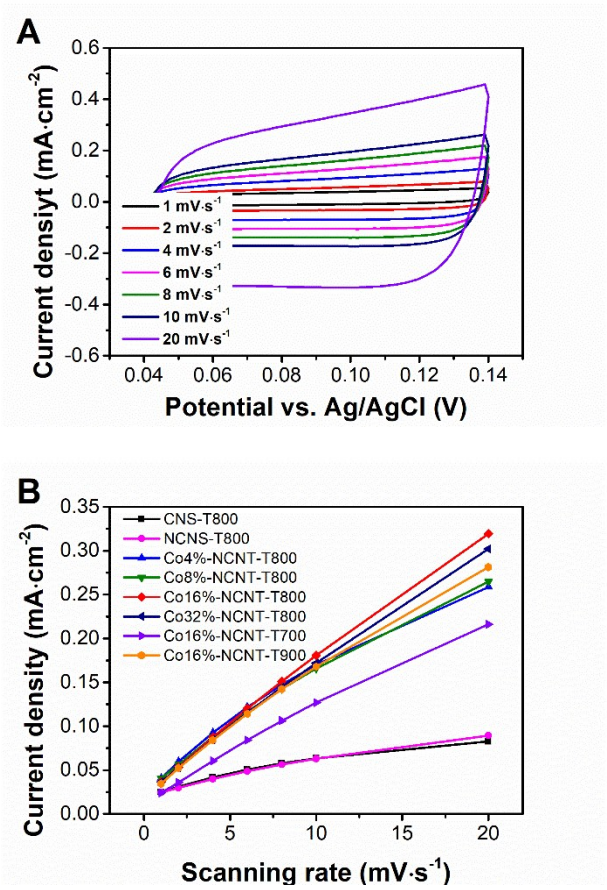

Figure S6. (A) Cyclic voltammeter corves for Co16%-NCNT-T800 at different scanning rate and (B) recorded current densities for catalysts at different scanning rate.

Table S3. Specific capacitance (C_S) calculated from CV curves of catalysts.

Catalysts	Current density at different Scanning rate ($mA \cdot cm^{-2}$)							C_S
	$1mV \cdot s^{-1}$	$2mV \cdot s^{-1}$	$4mV \cdot s^{-1}$	$6mV \cdot s^{-1}$	$8mV \cdot s^{-1}$	$10mV \cdot s^{-1}$	$20mV \cdot s^{-1}$	($mF \cdot cm^{-2}$)
CNS-T800	0.0249	0.03103	0.04195	0.05056	0.05776	0.06351	0.08276	2.97685
NCNS-T800	0.0246	0.02974	0.03996	0.04858	0.05623	0.06286	0.08939	3.37489
Co4%-NCNT-T800	0.04081	0.05962	0.09255	0.12155	0.1474	0.17009	0.25852	11.31282
Co8%-NCNT-T800	0.04057	0.05643	0.0877	0.11633	0.14263	0.16576	0.26462	11.72807
Co16%-NCNT-T800	0.03668	0.05356	0.08745	0.12018	0.15108	0.18069	0.31935	14.84685
Co32%-NCNT-T800	0.03667	0.05287	0.08474	0.11524	0.14437	0.17195	0.302	13.9238
Co16%-NCNT-T700	0.02415	0.03601	0.06057	0.08403	0.10632	0.12711	0.21627	10.10913
Co16%-NCNT-T900	0.03448	0.05234	0.08422	0.11427	0.14218	0.16795	0.28129	12.89651

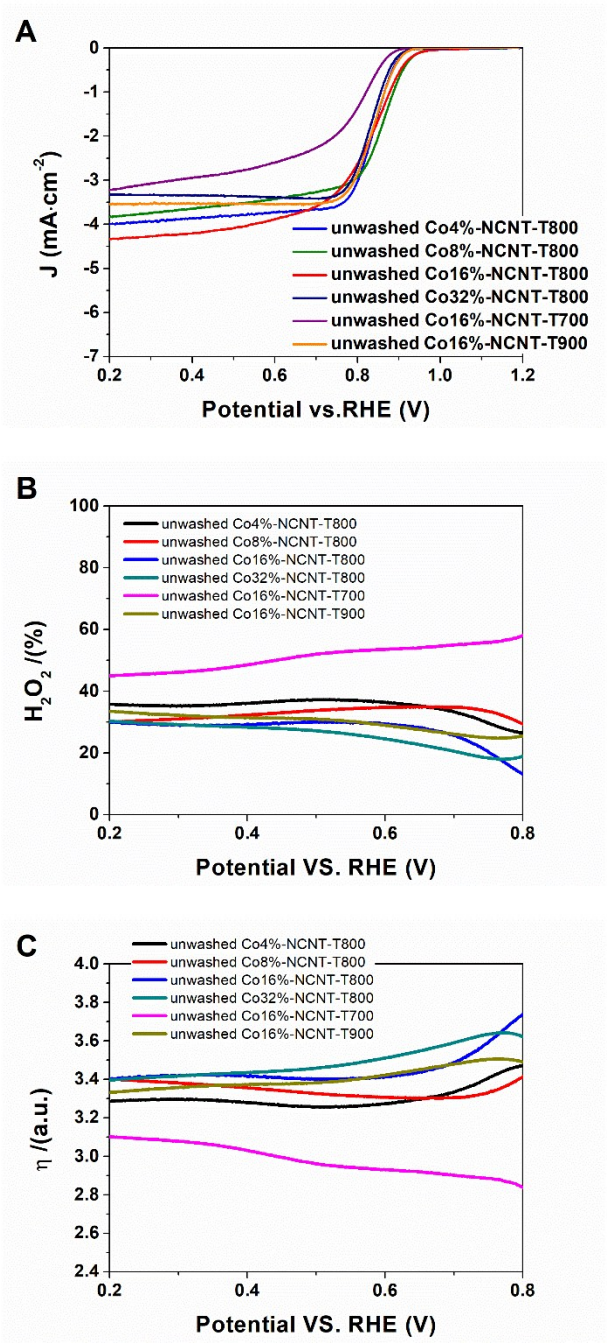

Figure S7. (A) LSV, (B) H_2O_2 yield and (C) electron transferring number for unwashed catalysts in O_2 saturated 0.1M KOH solution at the scan rate of 2 $mV \cdot s^{-1}$ and a rotation speed of 1600 rpm.