Electronic supplementary Material (ESI) for New Journal of Chemistry

Expanding interlamellar spacing of biomass-derived hydrids with intercalated nanotubes for enhanced oxygen reduction reaction

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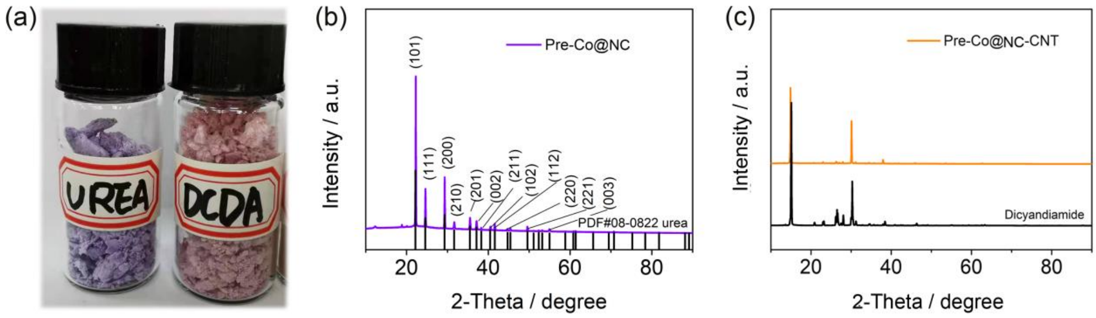

Fig. S1 (a) photograph of Pre-Co@NC (purple) and Pre-Co@NC-CNT (pink); (b) XRD pattern of Pre-Co@NC; (c) XRD pattern of Pre-Co@NC-CNT.

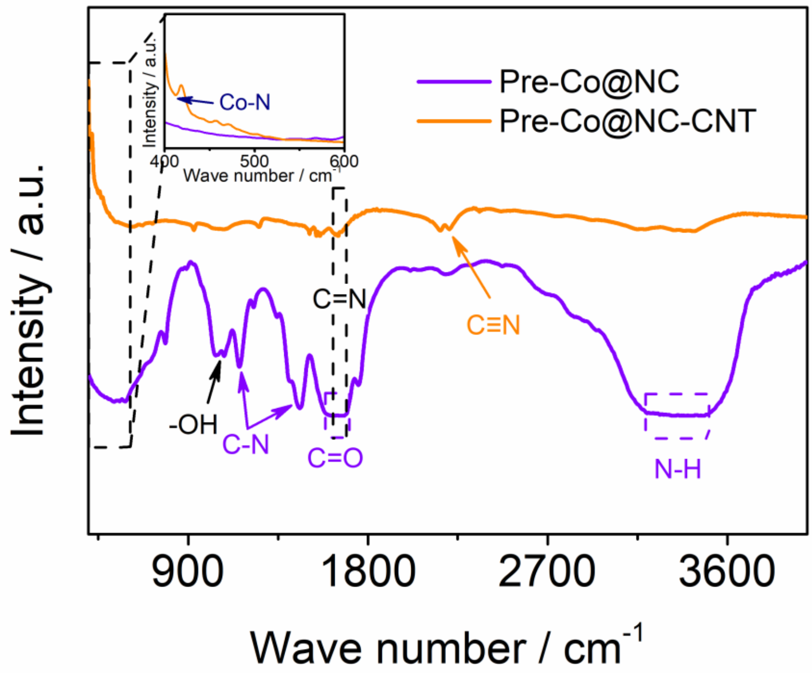

Fig. S2. FT-IR spectra of Pre-Co@NC and Pre-Co@NC-CNT.

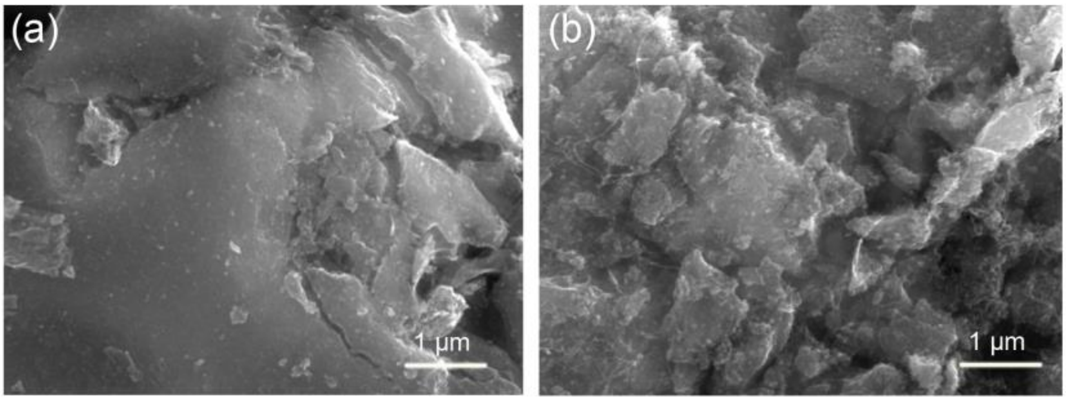

Fig. S3. Magnified SEM images of (a) Co@NC and (b) Co@NC-CNT.[1]

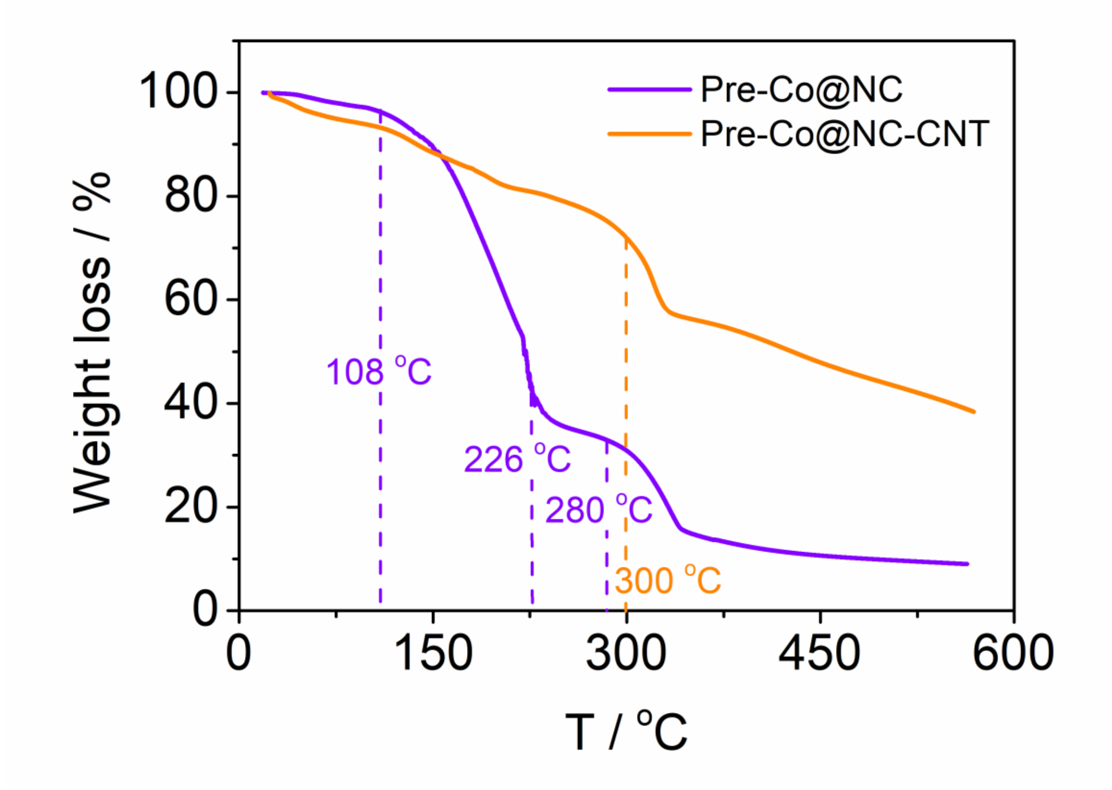

Fig. S4. TG curves of Pre-Co@NC and Pre-Co@NC-CNT measured from room temperature to 550 °C with a ramping rate of 10 °C min^{-1} under nitrogen atmosphere.

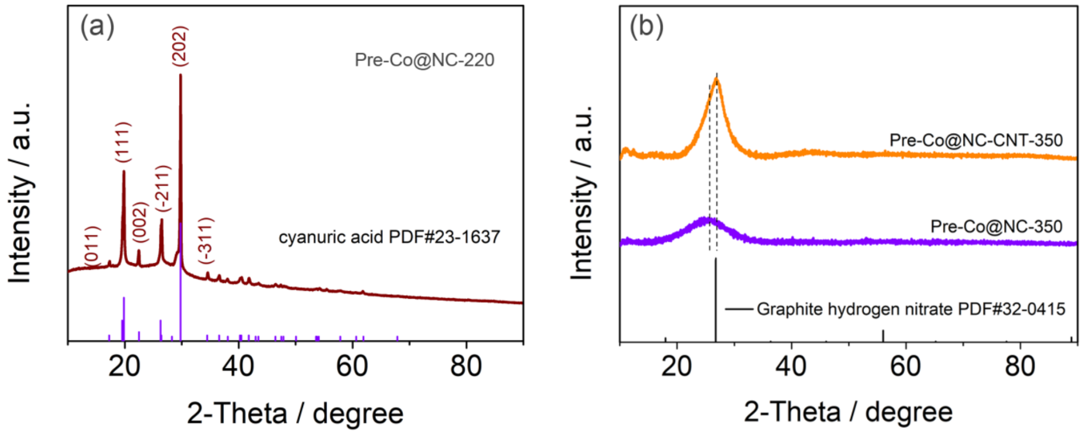

Fig. S5. XRD patterns of (a) pyrolyzed Pre-Co@NC at 220 ^{o}C; (b) Pre-Co@NC and Pre-Co@NC-CNT pyrolyzed at 350 ^{o}C.

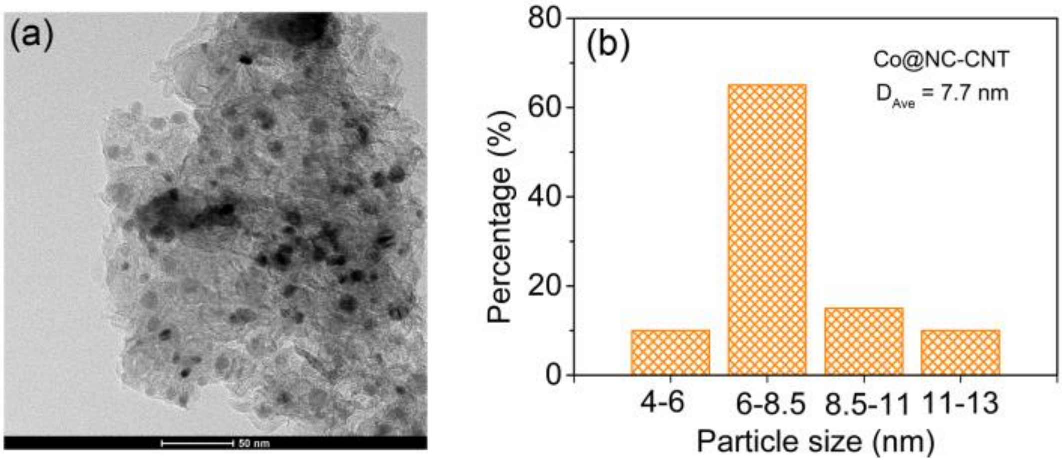

Fig. S6. (a) TEM images of Co@NC-CNT; (b) pore size distribution of Co@NC-CNT calculated according to the left TEM images.

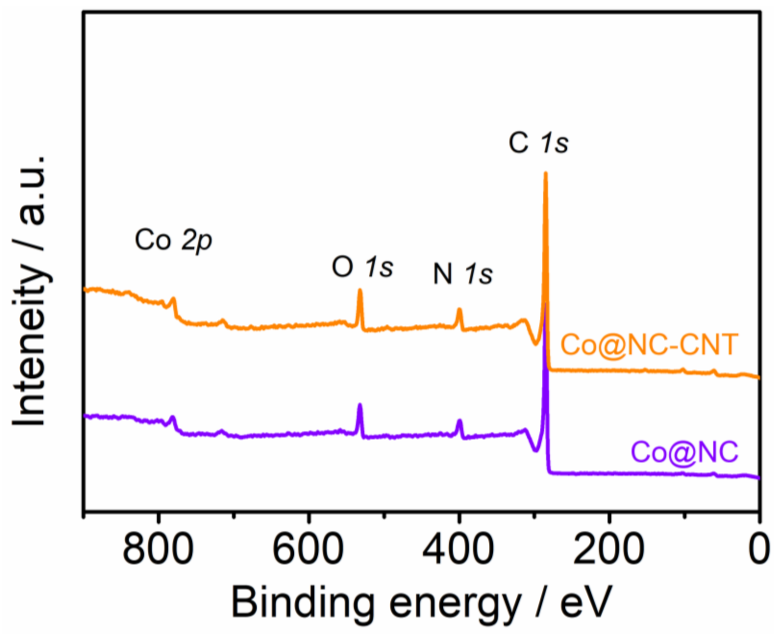

Fig. S7. XPS survey spectra of Co@NC and Co@NC-CNT.

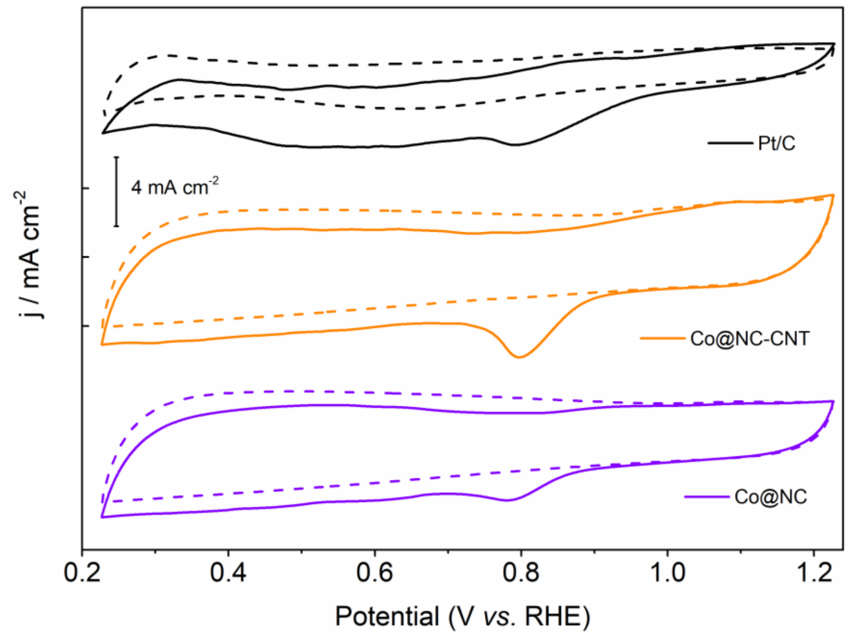

Fig. S8. CV curves of Co@NC, Co@NC-CNT and Pt/C measured in N_2- and O_2-saturated electrolyte at a scanning rate of 50 mV s^{-1}.

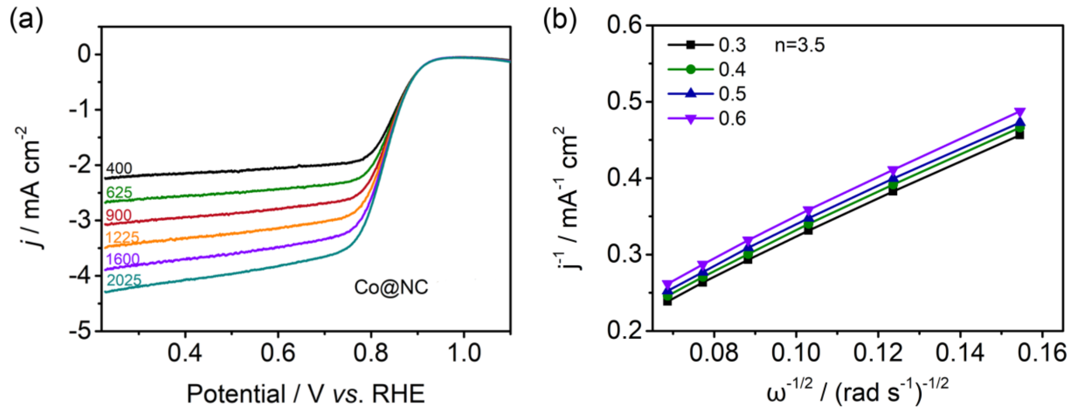

Fig. S9 (a) LSV curves of Co@NC at different rotating speed in O_2-saturated electrolyte with a scanning rate of 5 mV s^{-1}; (b) Koutechky-Levich (K-L) plots of Co@NC.

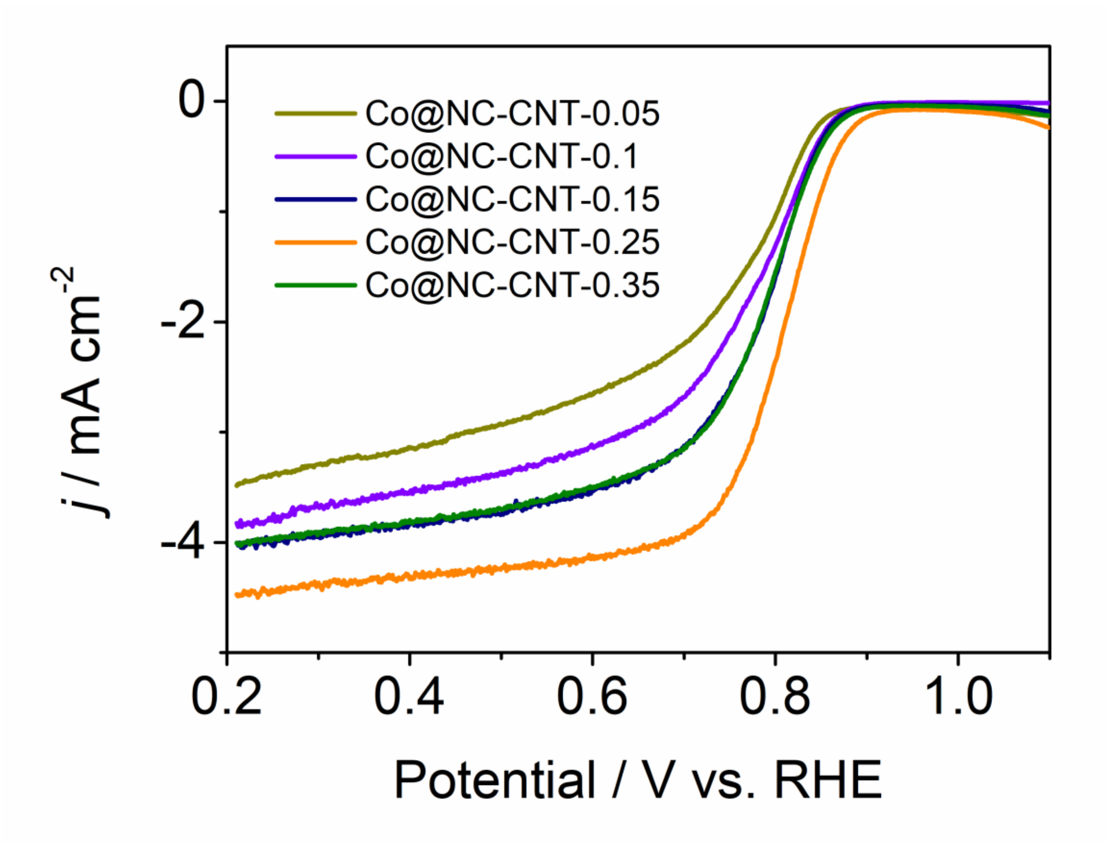

Fig. S10 LSV curves of Co@NC-CNT obtained using various Co content in precursor.

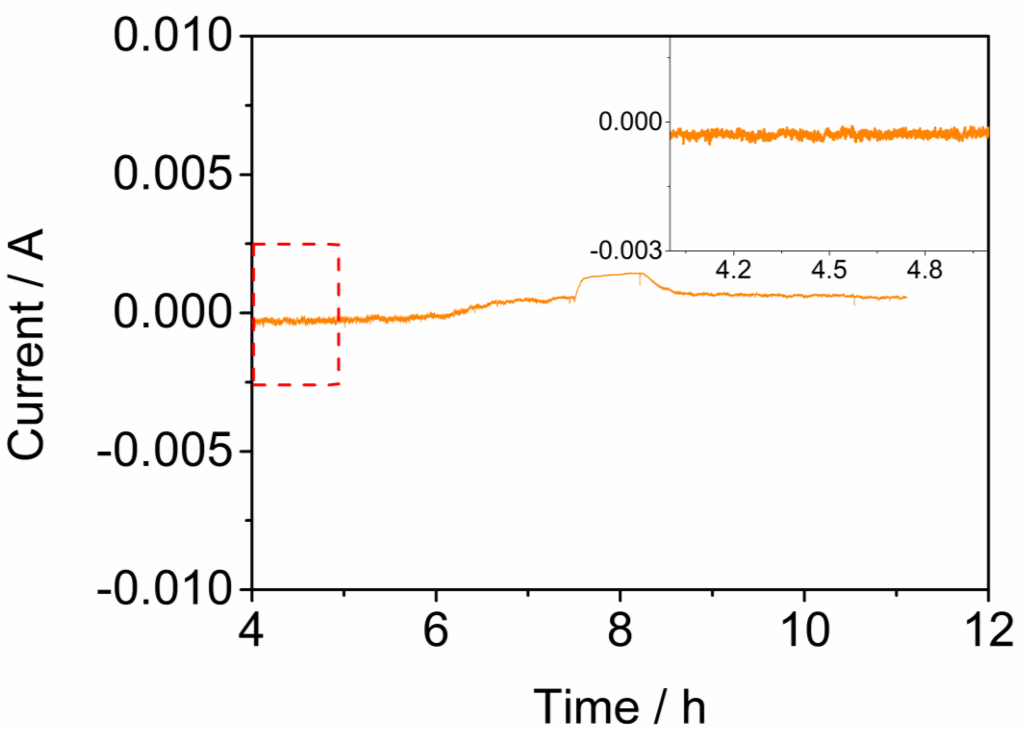

Fig. S11 Chronoamperometry curves of Co@NC-CNT exhibited from 15000 s to 40000 s.

Table S1 Relative percentage of micropores, mesopores and macropores.

	Pore volume (cm^3 g^{-1})	**Micropores (%)**	**Mesopores (%)**
Co@NC	0.17	45.9	40.6
Co@NC-CNT	0.29	21.1	76.2

Table S2 Summary of C, N, O, Co atomic contents of Co@NC and Co@NC-CNT from XPS analysis.

	C at.%	**N at.%**	**O at. %**	**Co at. %**
Co@NC	84.4	7.2	7.2	1.2
Co@NC-CNT	84.5	6.9	7.2	1.4

Table S3 Atomic percentage of different types of nitrogen of Co@NC-CNT-x (x refers to U, D, and M) from divided N 1s XPS spectra.

	N-6 % (398.7eV)	**Co-N % (399.5eV)**	**N-5 % (400.1eV)**	**N-G % (400.9eV)**	**N-O % (402.7eV)**
Co@NC	33.8	11.6	14.3	27.4	12.7
Co@NC-CNT	35.2	14.0	5.6	29.7	15.5

Table S4 Comparison of ORR electrocatalytic activity of Co@NC prepared from different nitrogen source. .

	N source	E_{onset} (V)	$E_{1/2}$ (V)	n	Co loading	Ref.
Co-DCDA-C	dicyandiamide	0.94*	0.847	3.9*	1.01 at.%	[2]
Co@NCNT	melamine	0.98	0.86	3.85	3.78 at.%	[3]
H-Co@FeCo/N/C	dopamine	1.03	0.91	3.9*	0.94 at.%	[4]
Co-N-CDC-CNT	dicyandiamide	0.91	0.82	3.6	0.11 at.%	[5]
CoNC-AT	dicyandiamide	0.924	0.82	3.6	1.60 at.%	[6]
Co/NC	Polypyrrole	0.94	0.86	3.95	0.75 at.%	[7]
Co-Cat-T500	melamine	0.96	0.86	3.7	--	[8]
Co/N-CNTs	ZIF-67	0.975	0.85	3.9	0.63 at.%	[9]
Co-NC-900	melamine	0.93*	0.84	3.75	0.25 at.%	[10]
Co@NC	urea	0.94	0.80	3.5	1.2 at.%	This work
Co@NC-CNT	dicyandiamide	0.97	0.85	3.9	1.4 at.%	This work

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