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

Supporting Information

Hierarchically Porous Nitrogen-Doped Carbon Nanotubes Derived from Core-shell ZnO@Zeolitic Imidazolate Framework Nanorods for Highly Efficient Oxygen Reduction Reactions

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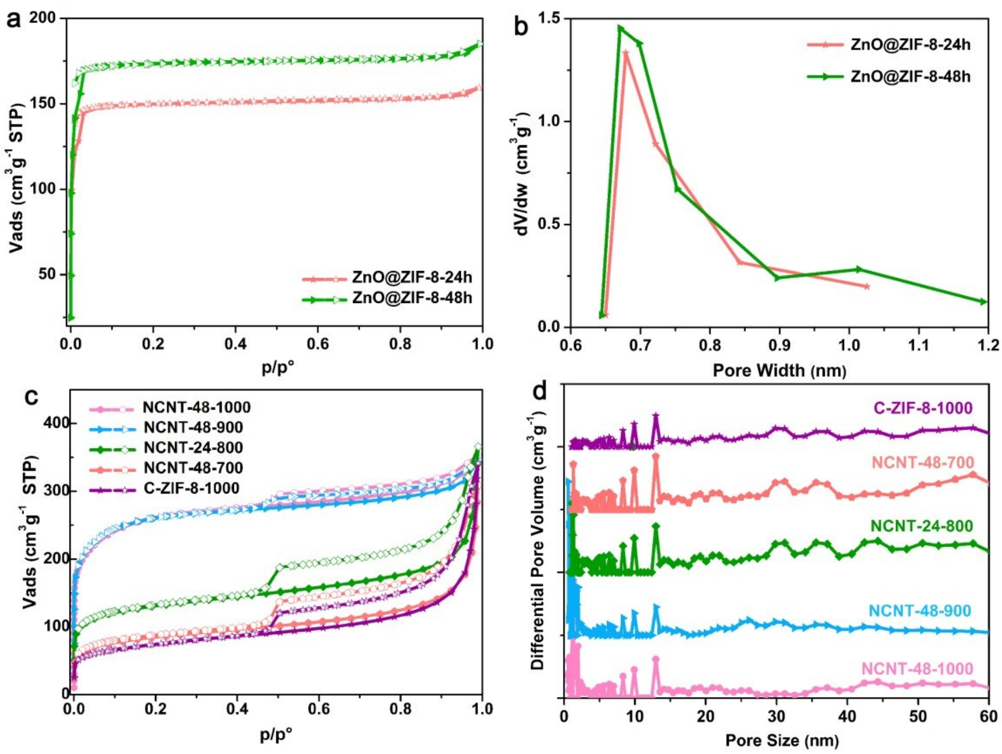

Fig. S1 (a) N_2 sorption isotherms of ZnO@ZIF-8-24h and ZnO@ZIF-8-48h. (b) The pore size distribution of ZnO@ZIF-8-24h and ZnO@ZIF-8-48h based on H-K method. (c) N_2 sorption isotherms of NCNTs and C-ZIF-8-1000. (d) Pore size distribution plots of NCNTs and C-ZIF-8-1000 based on the non-local density functional theory (NLDFT).

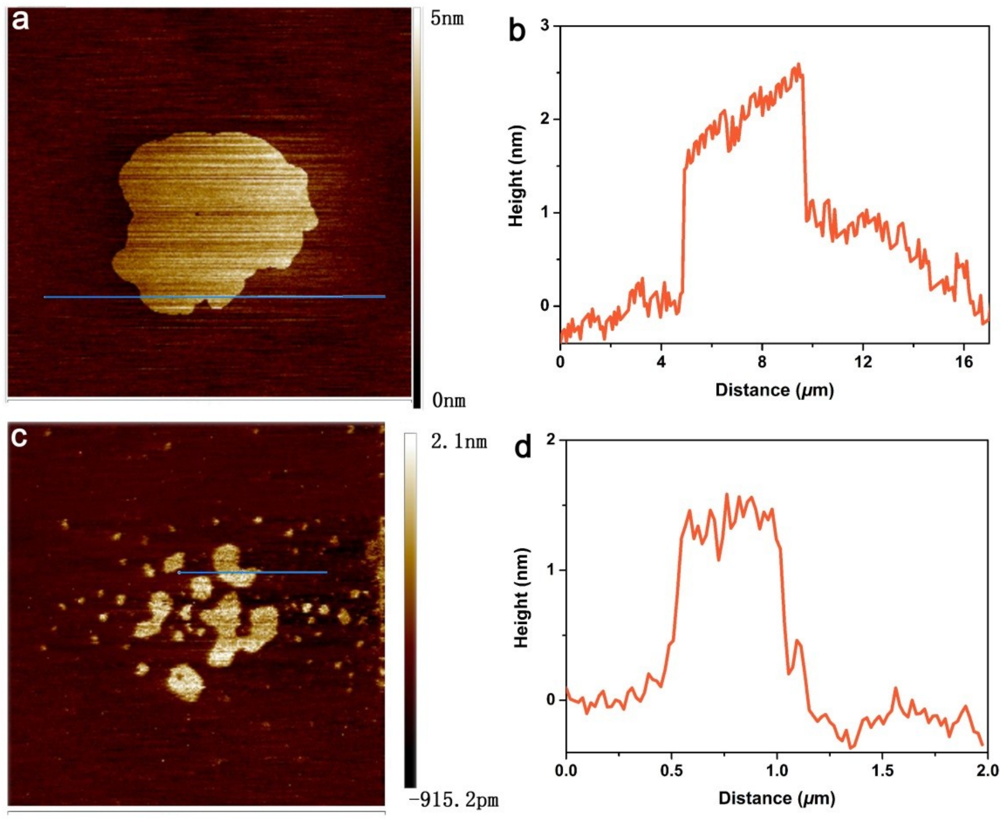

Fig. S2 (a) AFM image of NCNT-24-1000. (b) Height profile along the line scan in a. (c) AFM image of NCNT-48-1000. (d) Height profile along the line scan in c.

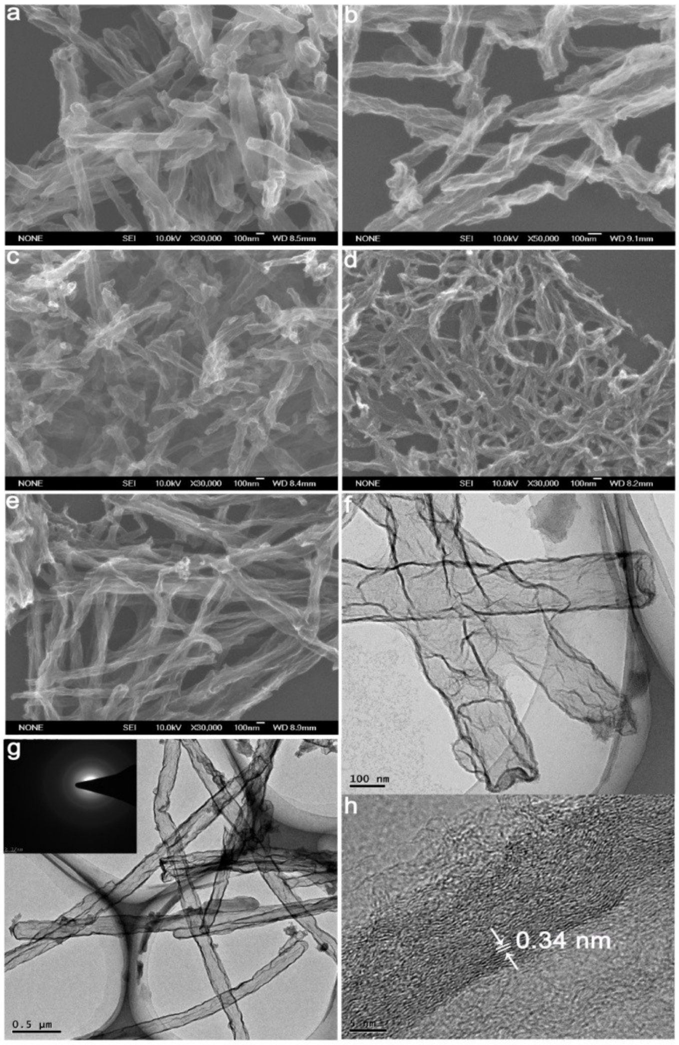

Fig. S3 SEM images (a) NCNT-48-800, (b) NCNT-24-900, (c) NCNT-48-900, (d) NCNT-24-1000, (e) NCNT-48-1000, TEM image (f) NCNT-24-1000, (g) NCNT-48-1000, inset in g the SAED pattern of NCNT-48-1000. (h) HRTEM image of NCNT-48-1000.

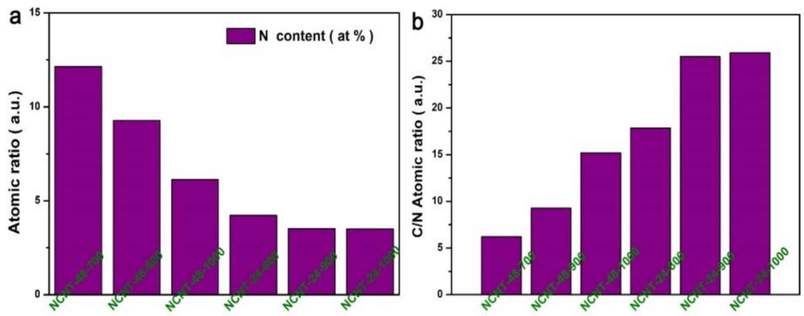

Fig. S4 N content (at %) and C/N atomic ratios in NCNTs based on XPS.

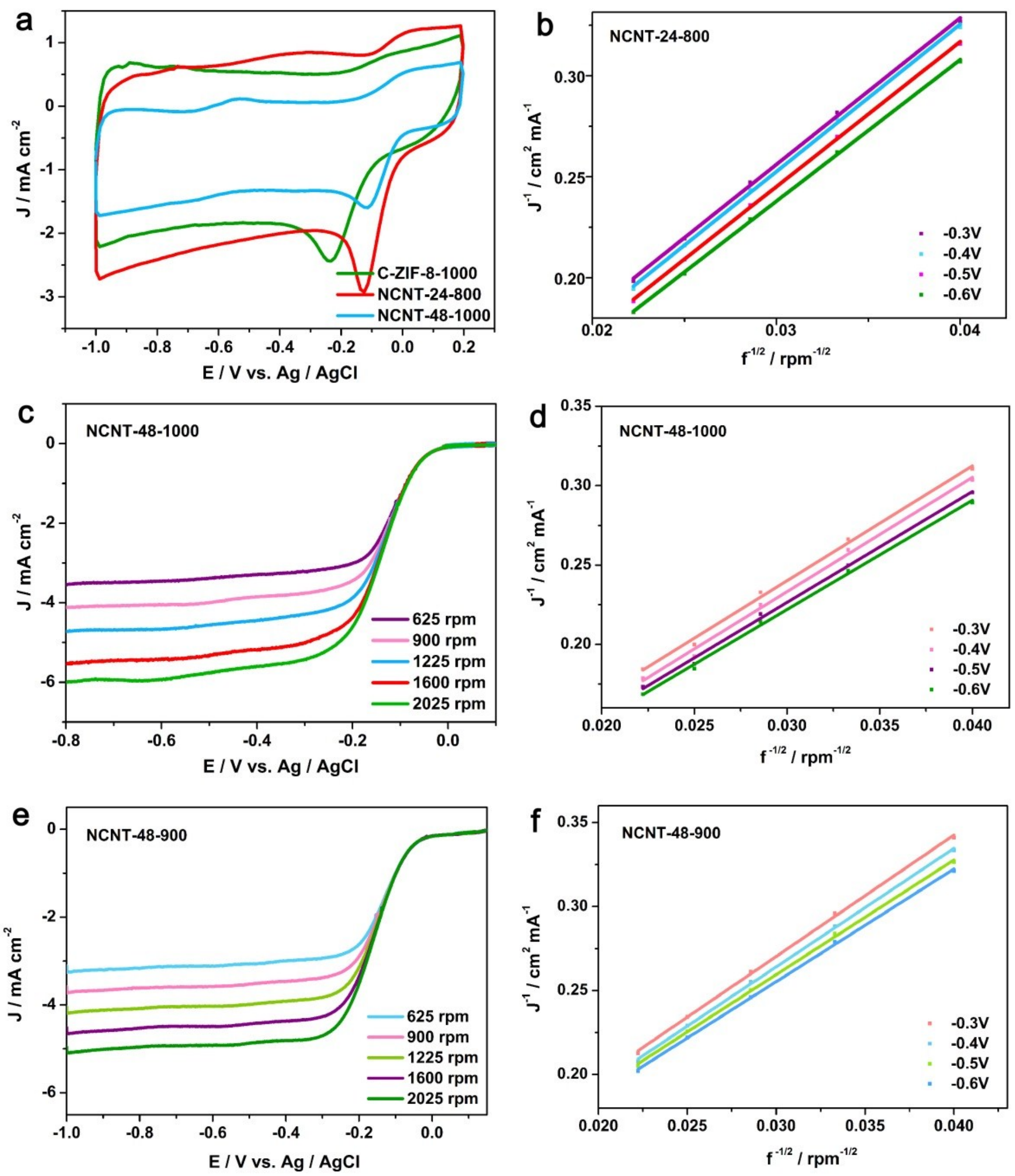

Fig. S5 (a) CV curves of NCNT-48-1000, C-ZIF-8-1000, NCNT-24-800. (b) K-L plots of NCNT-24-800 at different voltages. (c) LSVs of NCNT-48-1000 with various rotation speeds. (d) K–L plots of NCNT-48-1000 at different voltages. (e) LSVs of NCNT-48-900 with various rotation speeds. (f) K–L plots of NCNT-48-900 at different voltages.

Table S1. Comparison of ORR catalytic performances under alkaline conditions between metal-free NCNTs and carbons materials derived from MOFs in previous reports

Sample	Precursors	Onset potential (V) V *vs* RHE	Half-wave potential (V) V *vs* RHE	Current density (rpm)	Refs.
NCNT-24-800	ZnO@ZIF-8	1.025	0.862	5.68 (1600)	Present Work
NCNT-48-1000	ZnO@ZIF-8	0.995	0.831	5.5 (1600)	Present Work
GPC-1000-5	ZIF-8	0.876	0.705	5.66 (1600)	S1
P-Z8-Te-1000	Te@ZIF-8	0.895	-0.161	Not mentioned	S2
FeIM/ZIF-8	Fe-ZIF & ZIF-8 mixture	0.915	0.755 V	Not mentioned	S3
NC900	ZIF-8	0.83	Not mentioned	4.9 (2500)	S4
Co@Co3O4@C–CM	ZIF-9	0.93	0.81	Not mentioned	S5
FePhen@MOF-ArNH$_3$	ZIF-8 & 1,10-phenanthroline	1.03	0.86	Not mentioned	S6
ZIF-67-900	ZIF-67	0.91	0.85	5 (1600)	S7
Carbon-L	ZIF-7	0.861	0.697	4.59 (1600)	S8
MOFCN900	melamine & MOF-5	0.99	Not mentioned	4.2 (1600)	S9

The reversible hydrogen electrode (RHE) potential converts to the Ag/AgCl electrode using:
E (RHE) = E (Ag/AgCl) + 0.965 V.

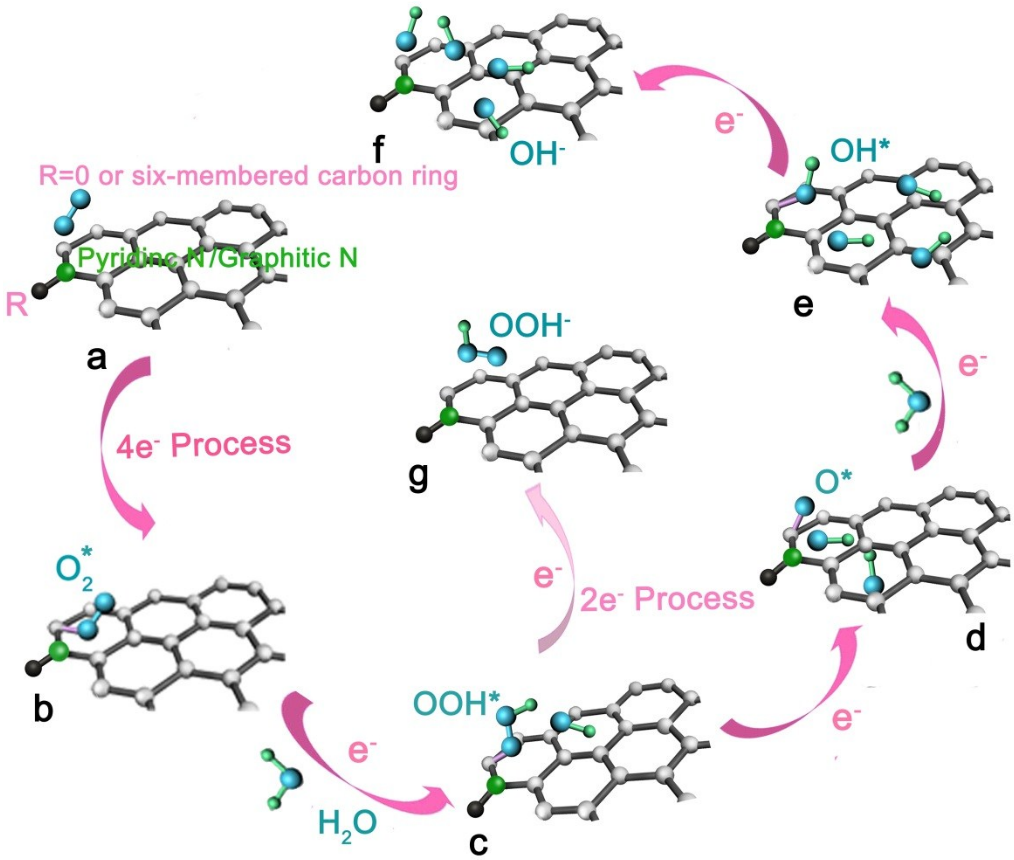

Fig. S6. A proposed mechanism of ORR catalyzed by NCNTs

Four-electron mechanism[S10]**:**

O_2 + * → O_2* (a→b)

O_2* + H_2O + e^- → OOH* + OH^- (b→c)

OOH* + e^- → O* + OH^- (c→d)

O* + H_2O + e^- → OH* + OH^- (d→e)

OH* + e^- → OH^- + *(e→f)

Two-electron mechanism:

O_2 + * → O_2* (a→b)

O_2* + H_2O + e^- → OOH* + OH^- (b→c)

OOH* + e^- → OOH^- + *(c→g)

References

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