Supporting Information

Nitrogen-Doped Porous Carbon from Biomass: Highly Efficient Trifunctional Electrocatalyst for Oxygen Reversible Catalysis and Nitrogen Reduction Reaction

Xiaoxuan Yang, Ke Li, Dongming Cheng, Wei-Lin Pang, Jiaqi Lv, Xinyu Chen, Hong-Ying Zang*, Xing-Long Wu*, Hua-Qiao Tan, Yong-Hui Wang and Yang-Guang Li*

Key Laboratory of Polyoxometalate Science of the Ministry of Education, Faculty of Chemistry, Northeast Normal University, Changchun, 130024, China.

*Corresponding authors. E-mail: zanghy100@nenu.edu.cn (Hong-Ying Zang)

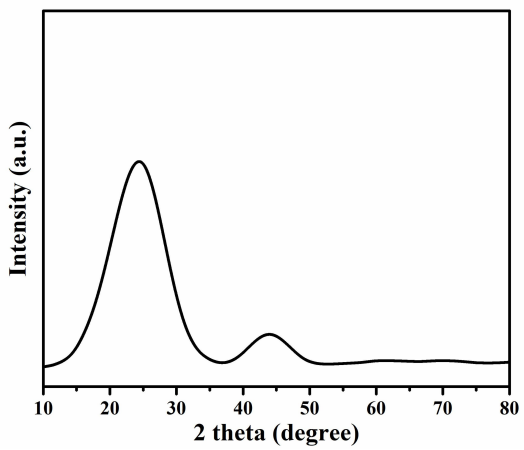

Fig. S1 X-ray diffraction of NCF-900.

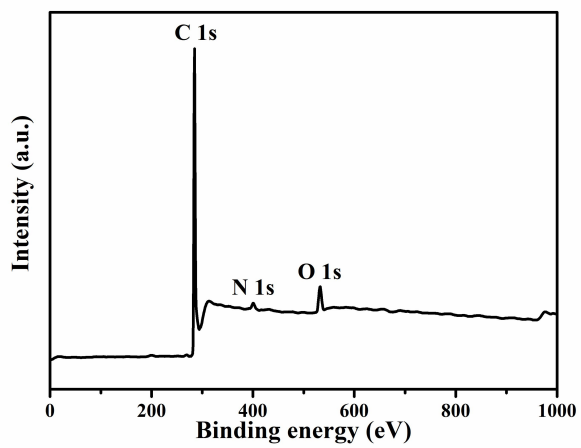

Fig. S2 XPS survey of NCF-900.

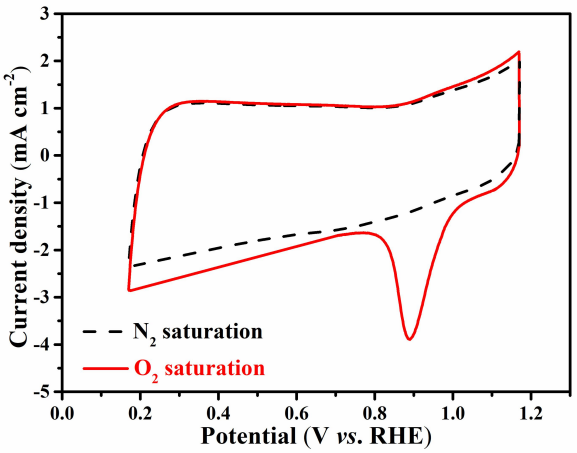

Fig. S3 Cyclic voltammograms in N_2-saturated and O_2-saturated 0.1 M KOH at room temperature and a scan rate of 5 mV s^{-1} for NCF-900 electrocatalysts.

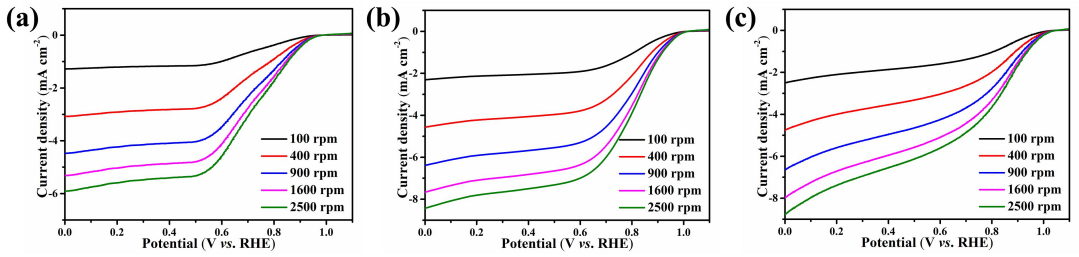

Fig. S4 LSV curves of (a) NCF-800, (b) NCF-850, (c) NCF-950 electrode with a sweep rate of 5 mV s^{-1} at the different rotation rates in O_2-saturated 0.1 M KOH solution.

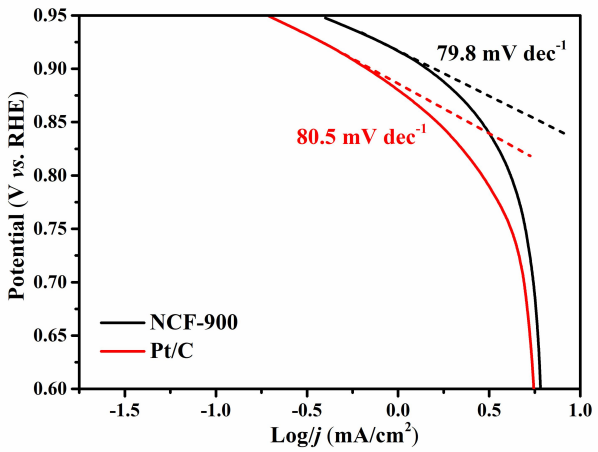

Fig. S5 The Tafel slope of NCF-900 and Pt/C.

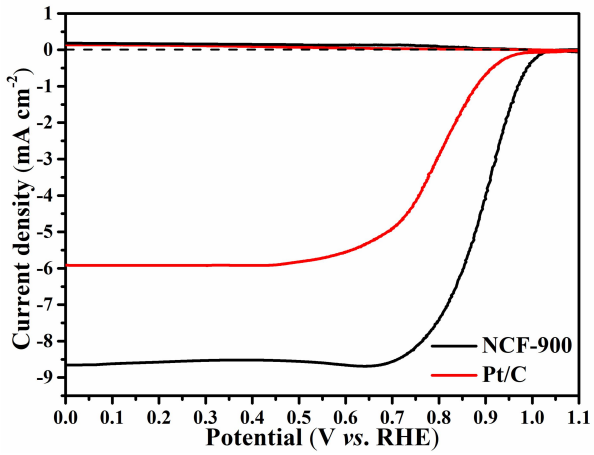

Fig. S6 RRDE polarization curves for NCF-900 in O_2-saturated 0.1 M KOH solution at 1600 rpm.

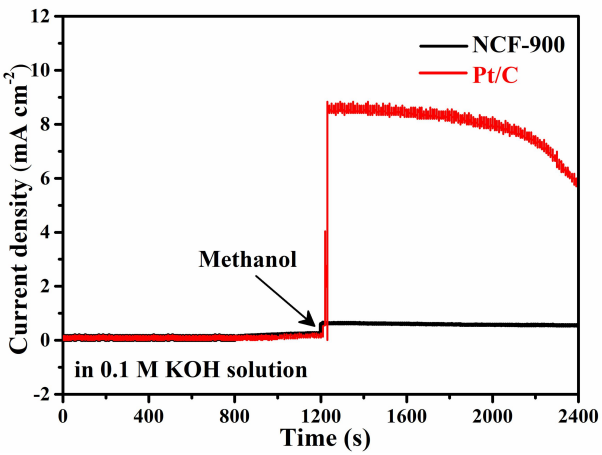

Fig. S7 Current–time (*I-t*) curves of NCF-900 and Pt/C in 0.1 M KOH with an addition of 1 M methanol.

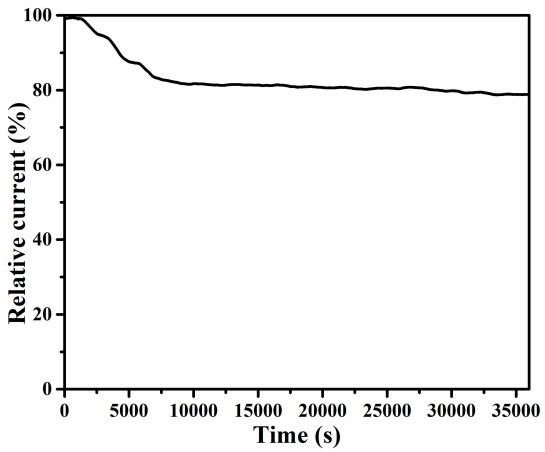

Fig. S8 Durability tests of the NCF-900 catalyst in 1 M KOH electrolyte.

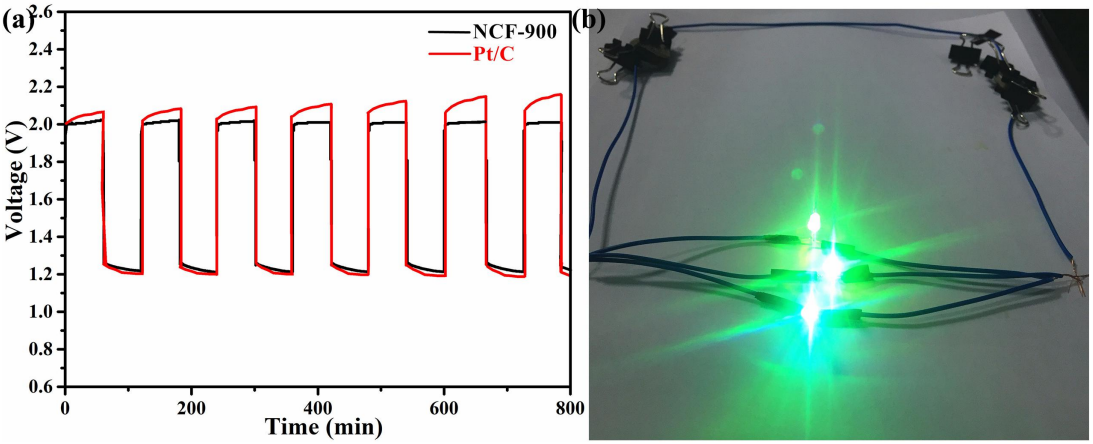

Fig. S9 a) Discharge and charge cycling of NCF-900 and Pt/C catalyst and b) Photograph of three LEDs powered by two Zn–air devices using NCF-900.

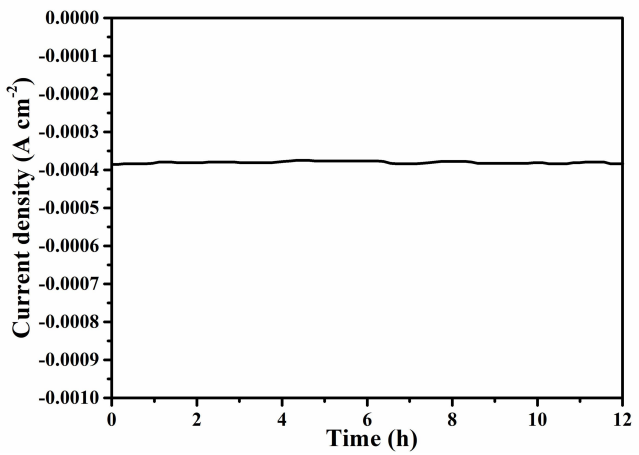

Fig. S10 Chrono-amperometry results towards NRR using NCF-900 material.

Table S1 Comparison of ORR performance of our NCNM-800 materials with other reported heteroatom-doped carbon electrocatalysts.

Material	**S_{BET} (m^2g)**	**Electrolyte**	**Onset potential (V)**	**n**	**Reference**
B-rGO	541	0.1 M KOH	-0.05 (Ag/AgCl)	4.16	*Green Chem.*, 2015, **17**, 3552–3560.
Nitrogen-doped carbon aerogels	450	0.1 M KOH	~-0.2 (Ag/AgCl)	~4	*Green Chem*., 2013, **15**, 2514–2524.
2D Nitrogen-doped Hierarchically Porous Carbon	2620	0.1 M KOH	0.945	---	*Appl. Catal. B*, 2017, **209**, 447–454
3D Interconnected Hierarchically Porous N-doped Carbon	2600	0.1 M KOH	0.98	3.75	*Appl. Catal. B,* 2017, **210**, 57–66.
Boron-Doped Graphene	200	0.1 M NaOH	~-0.1 (Ag/AgCl)	3.6~4.2	*Adv. Energy Mater*., 2015, **5**, 1500658.
Plasma-etched Carbon Cloth	--	0.1 M KOH	0.76 (RHE)	3.50	*Adv. Mater*., 2017, **29**, 1606207.

N and P co-doped mesoporous nanocarbon foams	1663	0.1 M KOH	0.94 (RHE)	~4.0	*Nat. Nanotechnol*., 2015, **10**, 444–452.
N-rGO	185	0.1 M KOH	-0.06 (SCE)	3.89	*Nano Energy,* 2014, **3**, 55–63.
N-carbon nanosheet	589	0.1 M KOH	0.72 (RHE)	3.67–3.91	*Angew. Chem., Int. Ed*., 2014, **53**, 1596–1600.
N-rGO aerogel	617	0.1 M KOH	-0.05 (Ag/AgCl)	3.66–3.92	*Small*, 2015, **11**, 1423–1429.
N-rGO	--	0.1 M KOH	-0.13 (Ag/AgCl)	3.75	*J. Chem. Sci.*, 2016, **128**, 339–347.
S-rGO	2129	0.1 M KOH	1.01 (RHE)	3.8	*Chem. Commun.*, 2014, **50**, 6382–6385.
S-rGO/carbon black	---	0.1 M KOH	-0.15 (Ag/AgCl)	3.84	*Electrochim. Acta*, 2014, **142**, 51–60.
S-rGO	496	0.1 M KOH	-0.40 (SCE)	3.13	*Nanoscale*, 2014, **6**, 13740–13747.
BN-graphene nanoribbons	875	0.1 M KOH	-0.1 (Ag/AgCl)	~3.9	*Chem. Mater*., 2015, **27**, 1181–1186.

SN-graphene	153	0.1 M KOH	-0.09 (Ag/AgCl)	2.9–3.2	*Adv. Mater*., 2014, **26**, 6186–6192.
SN-carbon	653	0.1 M KOH	0.85 (RHE)	3.82	*Carbon*, 2014, **69**, 294–301.
SN-mesoporous carbon	1100	0.1 M NaOH	-0.05 (Ag/AgCl)	3.1–4.0	*ACS Appl. Mater. Interfaces*, 2013, **5**, 12594–12601.
SN-graphene	800	0.1 M NaOH	-0.1 (Ag/AgCl)	4	*J. Mater. Chem. A*, 2016, **4**, 6014–6020.
SNP-rGO	301.6	0.1 M KOH	-0.03 (Ag/AgCl)	~4.0	*Carbon*, 2014, **78**, 257–267.
Carbon Nanotubes/Heteroatom-doped Carbon	---	0.1 M KOH	0.92	~4.0	*Angew. Chem. Int. Ed*., 2014, **53**, 4102–4106.
N,P-codoped ordered mesoporous carbon	1110	0.1 M KOH	0.92	3.7	*Angew. Chem. Int. Ed*., 2015, **54**, 9230–9234.
Triazine-Based Frameworks	2237	0.1 M KOH	0.86	3.7	*Adv. Mater*., 2015, **27**, 3190–3195.
NCMT-1000 (3D)	2358	0.1 M KOH	1.05	~4.0	*Energy Environ. Sci*., 2016, **9**, 3079–3084.

N and P codoped mesoporous nanocarbon	1663	0.1 M $HClO_4$	0.83	3.8	*Nat. Nanotechnol*., 2015, **10**, 444–452.
N doped carbon nanosheets	589	0.5 M H_2SO_4	0.72	3.67–3.91	*Angew. Chem. Int. Ed*., 2014, **53**, 1570–1574.
Sulfur and Nitrogen Codoped Carbon Tubes	500	0.5 M H_2SO_4	0.851	3.86–3.96	*Chem. Eur. J*., 2016, **22**, 10326–10329
NCS-800	646	0.1 M KOH	~0.8	3.90–3.97	*Energy Environ. Sci*., 2014, **7**, 4095–4103.
		0.5 M H_2SO_4	0.725	3.90–3.98	
N-doped Amorphous Carbon	1072	0.1 M KOH	0.211 V (SCE)	3.7	*Carbon*, 2017, **114**, 679–689.
3D nitrogen-doped carbon nanotube	---	0.1 M KOH	0.925 V	~4.0	*Nano Energy*, 2017, **37**, 98–107.
Nitrogen and Oxygen dual-doped Carbon	1462.5	0.1 M KOH	-0.060 V (SCE)	~4.0	*Nano Energy*, 2017, **33**, 334–342.
Nitrogen-doped Carbide-derived Carbon	2024	0.1 M KOH	-0.15 V (Ag/AgCl)	3.5	*Carbon*, 2017, **113**, 159–169.

N-doped carbon	164.34	0.1 M KOH	0.759 V	3.7	*J. Mater. Chem. A*, 2017, **5**, 2073–2082.
Nitrogen-doped graphene	741	0.1 M KOH	0.72 V	3.75–3.88	*Nano Res.*, 2017, **10**, 305–319.
N-doped carbon foams	**1547.13**	**0.1 M KOH**	**1.055**	**~4**	**This work**

Table S2 Comparison study of some recently reported bi-functional ORR/OER catalysts in alkaline electrolyte.

Catalyst	**OER Ej=10 (V *vs.* RHE)**	**ORR E1/2 (V *vs.* RHE)**	**ΔE (Ej=10 - E1/2) (V)**	**Electrolyte**	**Reference**
MnO_x Film	1.77	0.73	1.04	0.1 M KOH	J. Am. Chem. Soc. 2010, 132, 13612
Co_3O_4/N-doped graphene	1.54	0.83	0.71	1 M KOH	Nat. Mater. 2011, 10, 780
H-Pt/$CaMnO_3$	1.80	0.79	1.01	0.1 M KOH	Adv. Mater. 2014, 26, 2047
Mn_xO_y/N-doped carbon	1.68	0.81	0.87	0.1 M KOH	Angew. Chem. Int. Ed. 2014, 53, 8508
CoO/N-doped graphene	1.57	0.81	0.76	1 M KOH	Energy Environ. Sci. 2014, 7, 609
Fe@N-C	1.71	0.83	0.88	0.1 M KOH	Nano Energy 2015, 13, 387
P-doped C_3N_4 on carbon-fiber paper	1.63	0.67	0.96	0.1 M KOH	Angew. Chem. Int. Ed. 2015, 54, 4646
N-doped porous carbon fiber	1.84	0.82	1.02	0.1 M KOH	Adv. Mater. 2016, 28, 3000
N, S-doped carbon nanosheet	1.65	0.77	0.88	0.1 M KOH	Nano Energy 2016, 19, 373
N-doped graphene	1.66 (1.59)	0.84 (0.84)	0.82 (0.75)	0.1 M KOH (1 M KOH)	Sci. Adv. 2016, 2:e1501122
N-doped carbon foams	**1.62**	**0.89**	**0.73**	**0.1 M KOH**	**This work**