Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.
This journal is © The Royal Society of Chemistry 2015

Supporting Information

MOF Derived Co_3O_4 Nanoparticles Embedded in N-Doped Mesoporous Carbon Layer/MWCNTs Hybrids: Extraordinary Bi-functional Electrocatalysts for OER and ORR

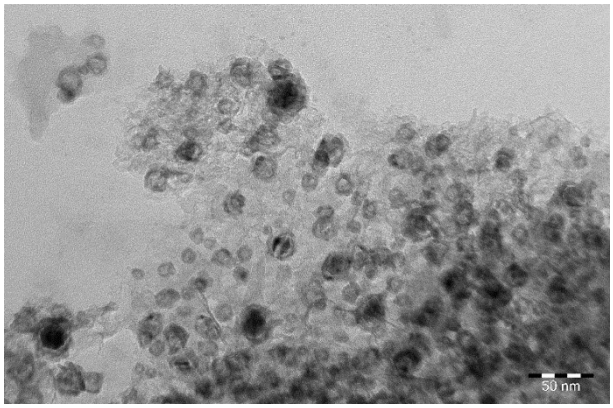

Fig. S1 TEM characterization of Co_3O_4@C derived from pure MOF, demonstrating the formation of graphitic carbon layer.

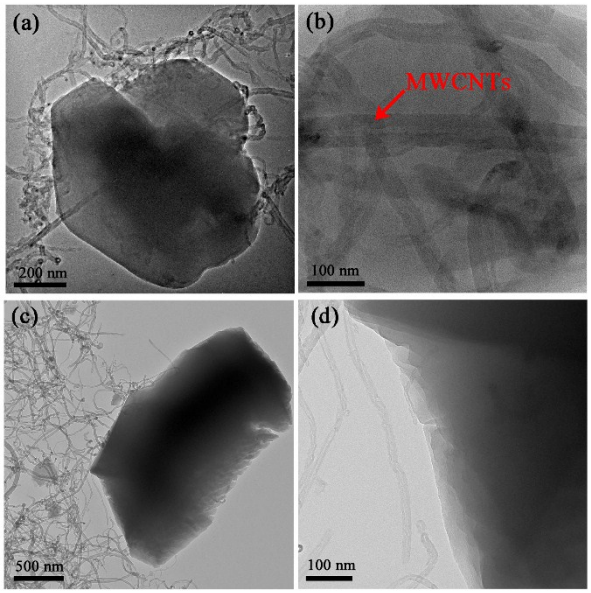

Fig. S2 TEM images of (a, b) MOF-MWCNTs and (c, d) physical mixed MOF+MWCNTs (image b is a local of a; image d is a local of c).

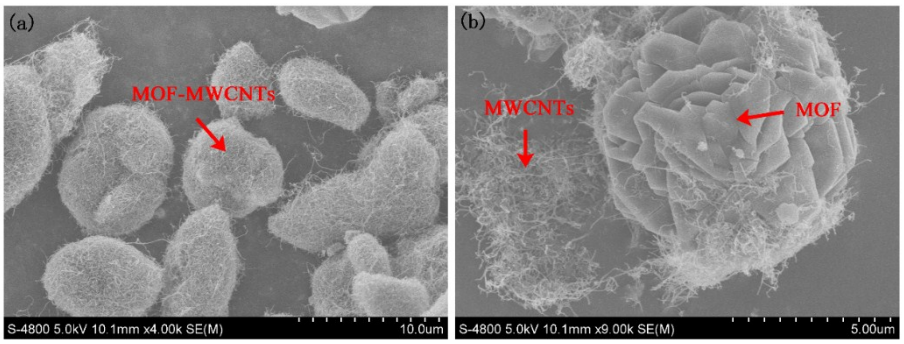

Fig. S3 SEM images of (a) MOF-MWCNTs and (b) physical mixed MOF+MWCNTs.

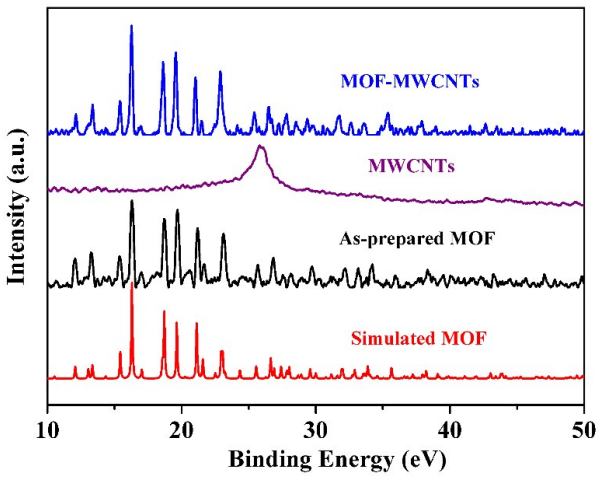

Fig. S4 XRD patterns of the simulated MOF, as-prepared MOF, MWCNTs and MOF-MWCNTs.

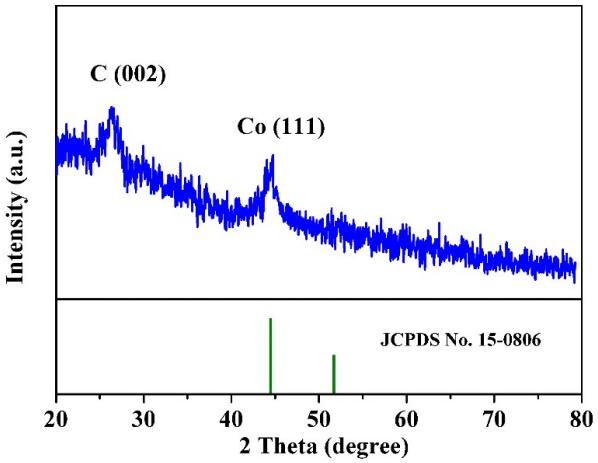

Fig. S5 XRD pattern of the Co@C-MWCNTs, obtained by carbonization of MOF-MWCNTs under argon atmosphere.

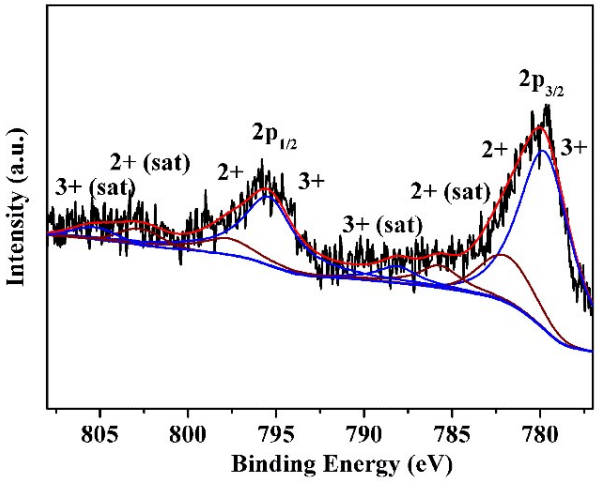

Fig. S6 High resolution XPS spectrum of Co 2p of Co_3O_4-MWCNTs.

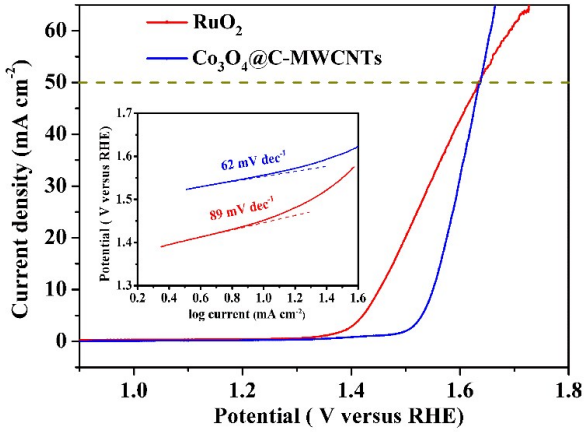

Fig. S7 LSVs curves of Co_3O_4@C-MWCNTs and RuO_2 in an O_2-saturated 1.0 M KOH solution (Inset: the corresponding Tafel plot of the catalysts above).

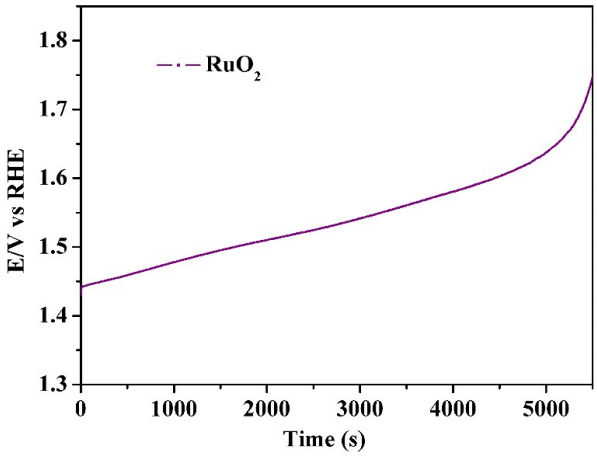

Fig. S8 Chronopotentiometry curve of RuO_2 under a current density of 10 mA cm^{-2} in 1.0 M KOH.

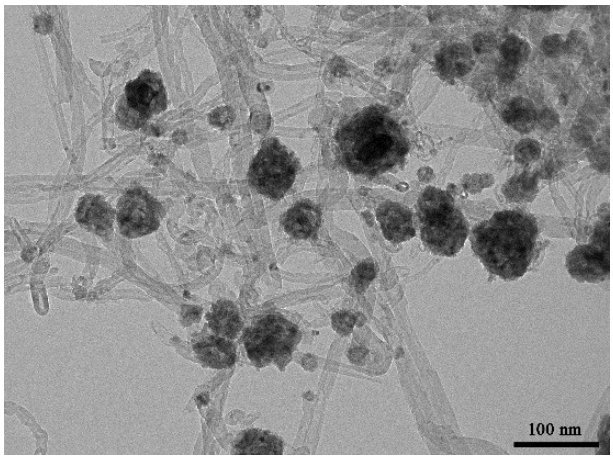

Fig. S9 TEM image of Co_3O_4-MWCNTs prepared via a conventional wet-impregnation method.

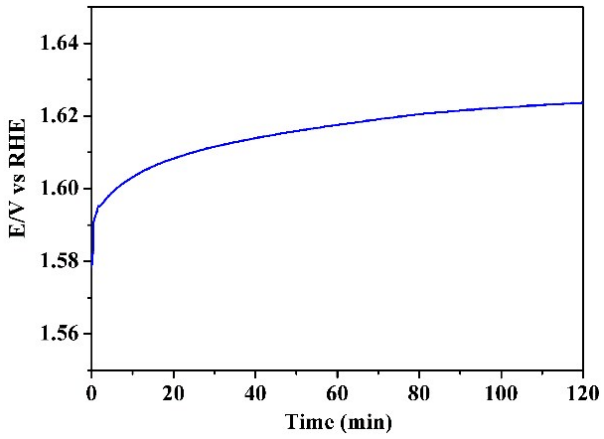

Fig. S10 Chronopotentiometry curve of Co_3O_4-MWCNTs under a current density of 10 mA cm^{-2} in 1.0 M KOH.

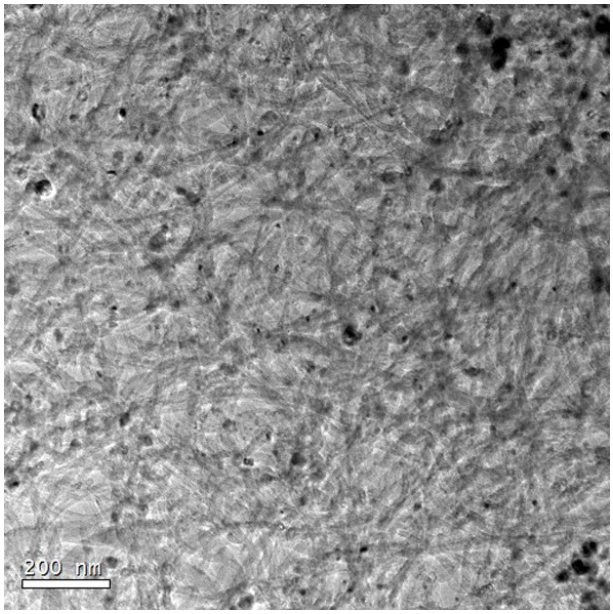

Fig. S11 TEM characterization of Co_3O_4@C-MWCNTs after OER test.

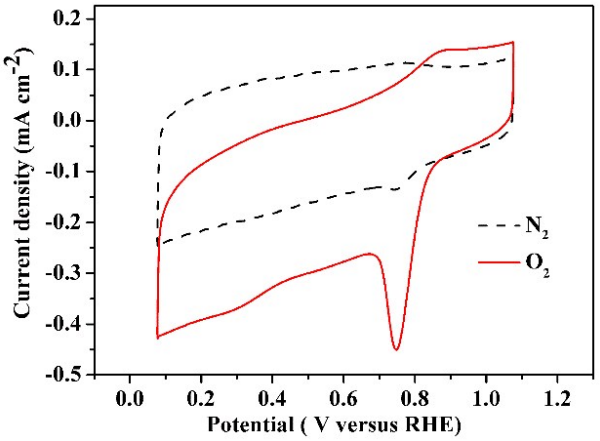

Fig. S12 CVs of Co_3O_4@C in N_2-saturated or O_2-saturated 0.1 M KOH at scanning rate of 50 mV s^{-1}.

Table S1: Comparison of the OER activity for several recently reported highly active catalysts.

Catalyst	Onset potential (V)	η@10.0 mA cm^{-2} (V)	Tafel slope ($mV\ dec^{-1}$)	Mass loading ($mg\ cm^{-2}$)	Electrolyte	Reference
Co_3O_4@C-MWCNTs	1.50	0.32	62	0.29	1.0 M KOH	This work
N-doped graphene-CoO	~ 1.52	0.34	71	0.7	1.0 M KOH	[1]
Co_3O_4/N -rmGO	1.50	0.31	67	1	1.0 M KOH	[2]
$Zn_xCo_{3-x}O_4$ nanowire array	~ 1.50	0.32	51	~ 1	1.0 M KOH	[3]
$Ni_xCo_{3-x}O_4$ nanowire	N.A.	~ 0.37	59–64	2.3–2.7	1.0 M KOH	[4]
NiCo LDH nanosheets	~ 1.53	0.37	40	1.73	1.0 M KOH	[5]
CoO_x	N.A.	0.42	42	N.A.	1.0 M KOH	[6]
$Ni_{0.5}Co_{0.5}O_x$	N.A.	0.36	37	N.A.	1.0 M KOH	[6]
CoCo LDH	N.A.	0.39	59	N.A.	1.0 M KOH	[7]
$Co_{0.5}Fe_{0.5}S$@N-MC	1.55	0.41	159	0.8	1.0 M KOH	[8]
Au@Co_3O_4/C	1.52	0.38	60	0.20	0.1 M KOH	[9]
Co_3O_4 /mMWCNT	1.51	0.39	N.A.	0.21	0.1 M KOH	[10]
$Mn_3O_4/CoSe_2$	N.A.	0.45	49	0.2	0.1 M KOH	[11]

1. S. Mao, Z. Wen, T. Huang, Y. Hou and J. Chen, *Energy Environ. Sci.*, 2014, 7, 609-616.
2. Y. Liang, Y. Li, H. Wang, J. Zhou, J. Wang, T. Regier and H. Dai, *Nat. Mater.*, 2011, 10, 780-786.
3. X. Liu, Z. Chang, L. Luo, T. Xu, X. Lei, J. Liu and X. Sun, *Chem. Mater.*, 2014, 26, 1889-1895.
4. Y. Li, P. Hasin and Y. Wu, *Adv. Mater.*, 2010, 22, 1926-1929.
5. H. Liang, F. Meng, M. Caban-Acevedo, L. Li, A. Forticaux, L. Xiu, Z. Wang and S. Jin, *Nano Lett.*, 2015, 15, 1421-1427.
6. L. Trotochaud, J. K. Ranney, K. N. Williams and S. W. Boettcher, *J. Am. Chem. Soc.*, 2012,

134, 17253-17261.
7. F. Song and X. Hu, *Nat. Commun.*, 2014, 5, 4477.
8. M. Shen, C. Ruan, Y. Chen, C. Jiang, K. Ai and L. Lu, *ACS Appl. Mater. Interfaces*, 2015, 7, 1207-1218.
9. Z. Zhuang, W. Sheng and Y. Yan, *Adv. Mater.*, 2014, 26, 3950-3955.
10. X. Lu and C. Zhao, *J. Mater. Chem. A*, 2013, 1, 12053-12059.
11. M. R. Gao, Y. F. Xu, J. Jiang, Y. R. Zheng and S. H. Yu, *J. Am. Chem. Soc.*, 2012, 134, 2930-2933.