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Hierarchically porous Fe,N-doped carbon nanorods derived from 1D Fe-doped MOFs as highly efficient oxygen reduction electrocatalysts in both alkaline and acidic media

The authors regret that an incorrect image was used in Figure S3, panel *i* for the TEM images of 3Fe-N/C-NR, and Figure S3 has therefore been replaced in this document. The original Figure S3 and caption is displayed below for future reference:

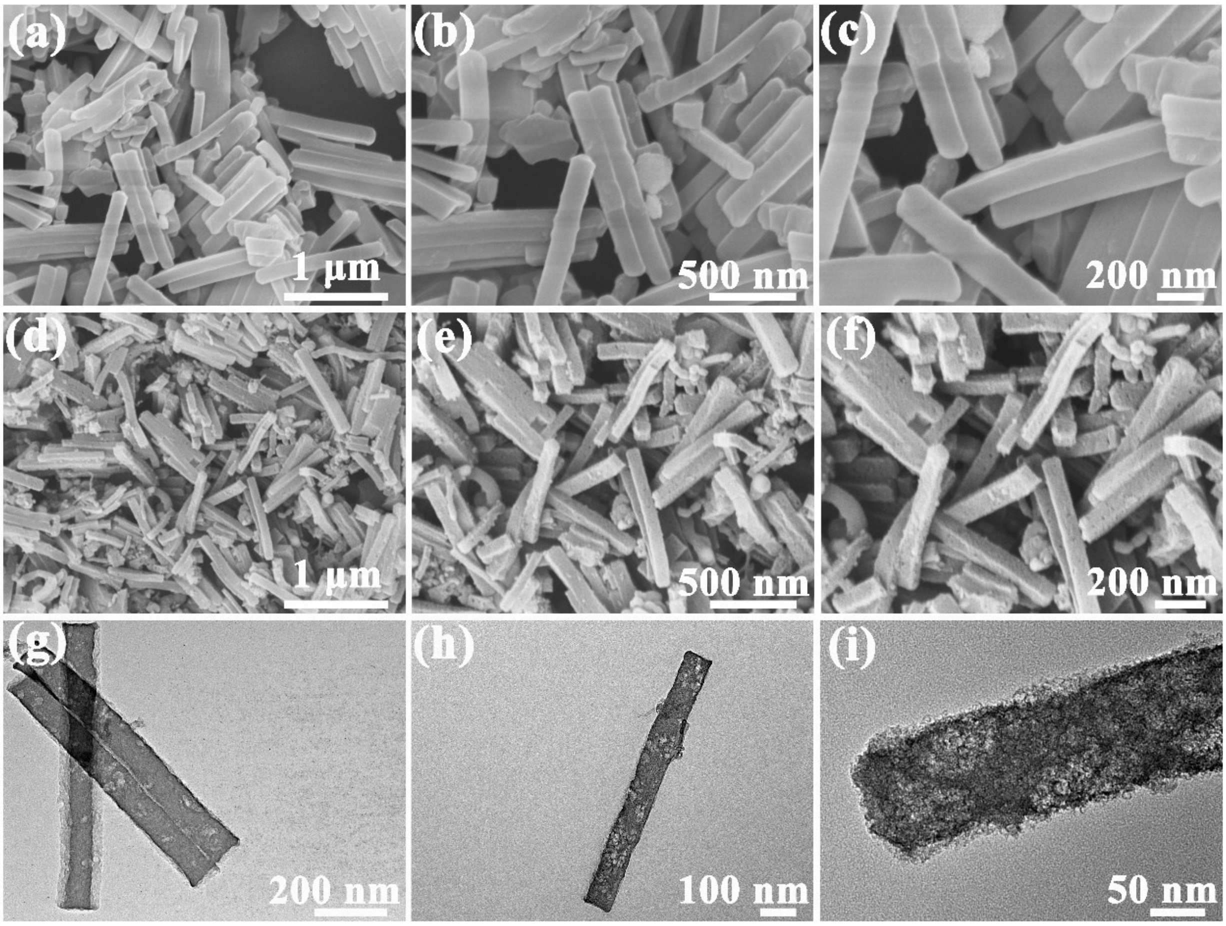

Figure S3. SEM images of (a, b, c) 3Fe-ZIF-NR and (d, e, f) 3Fe- N/C-NR; TEM images of (g, h, i) 3Fe-N/C-NR.

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Supporting Information

Hierarchically Porous Fe, N-doped Carbon Nanorods Derived from 1D Fe-doped MOF as Highly Efficient Oxygen Reduction Electrocatalysts in Both Alkaline and Acidic Media

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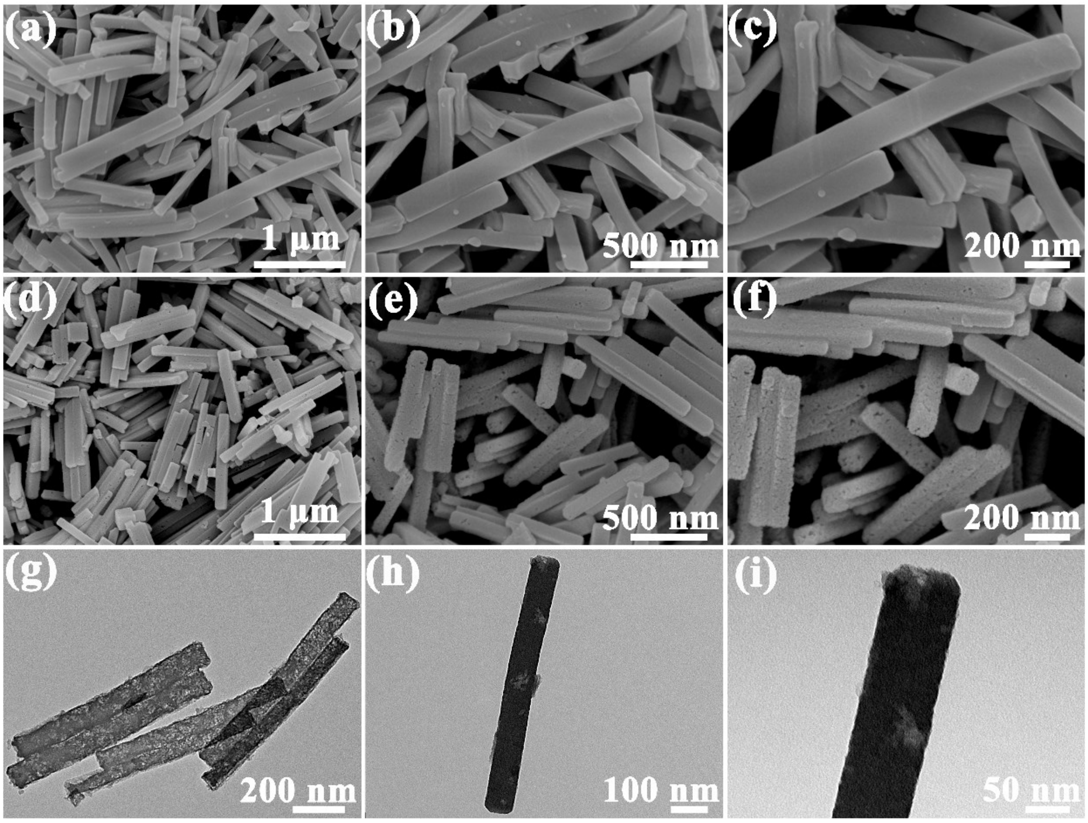

Figure S1. SEM images of (a, b, c) ZIF-8-NR and (d, e, f) N/C-NR; TEM images of (g, h, i) N/C-NR.

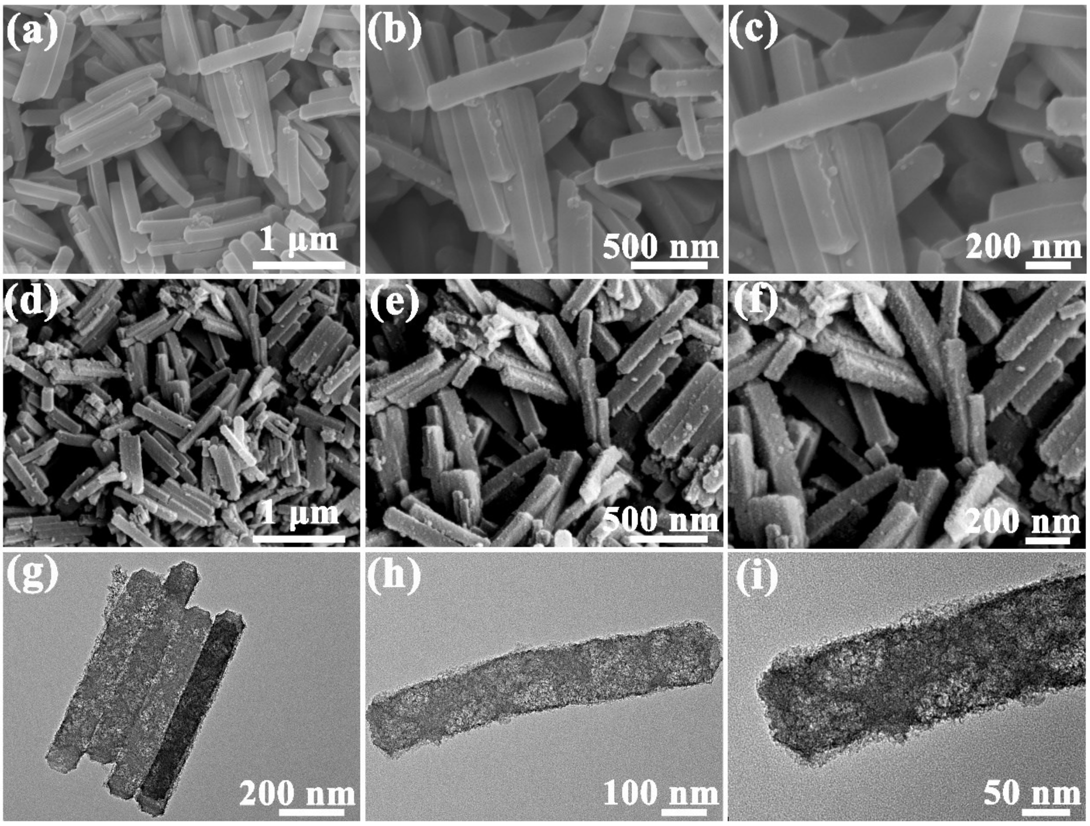

Figure S2. SEM images of (a, b, c) 1Fe-ZIF-NR and (d, e, f) 1Fe- N/C-NR; TEM images of (g, h, i) 1Fe-N/C-NR.

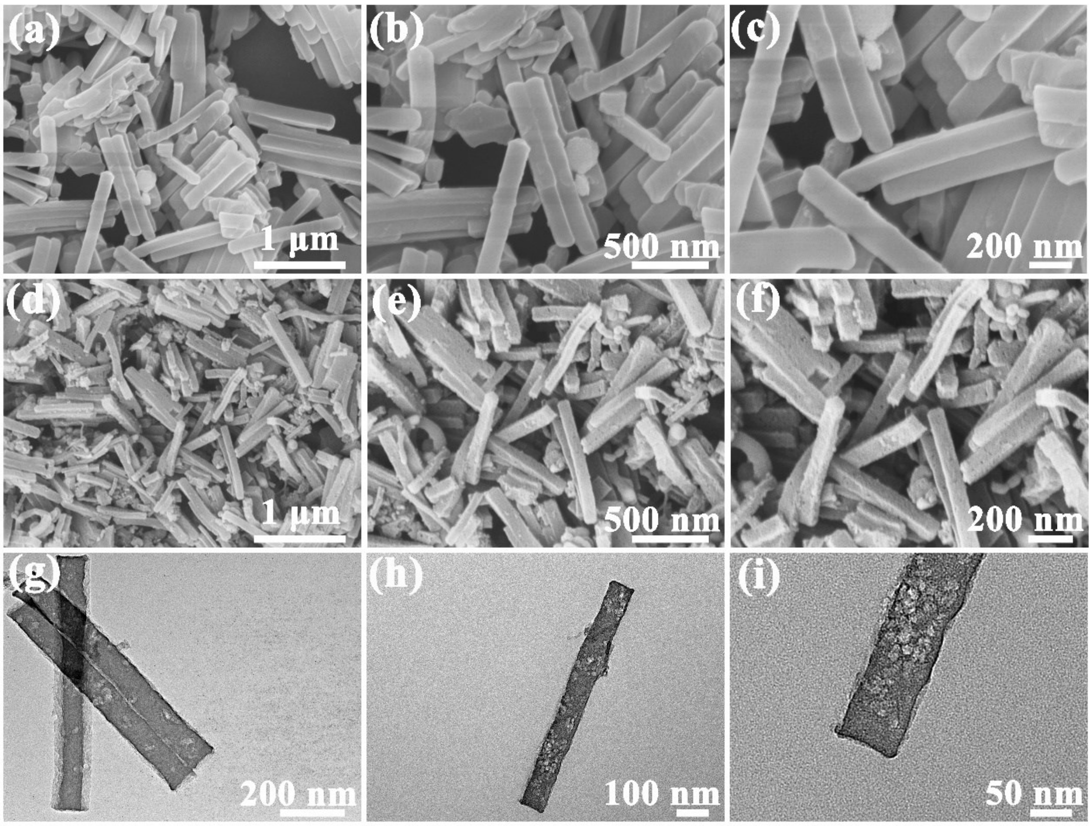

Figure S3. SEM images of (a, b, c) 3Fe-ZIF-NR and (d, e, f) 3Fe- N/C-NR; TEM images of (g, h, i) 3Fe-N/C-NR.

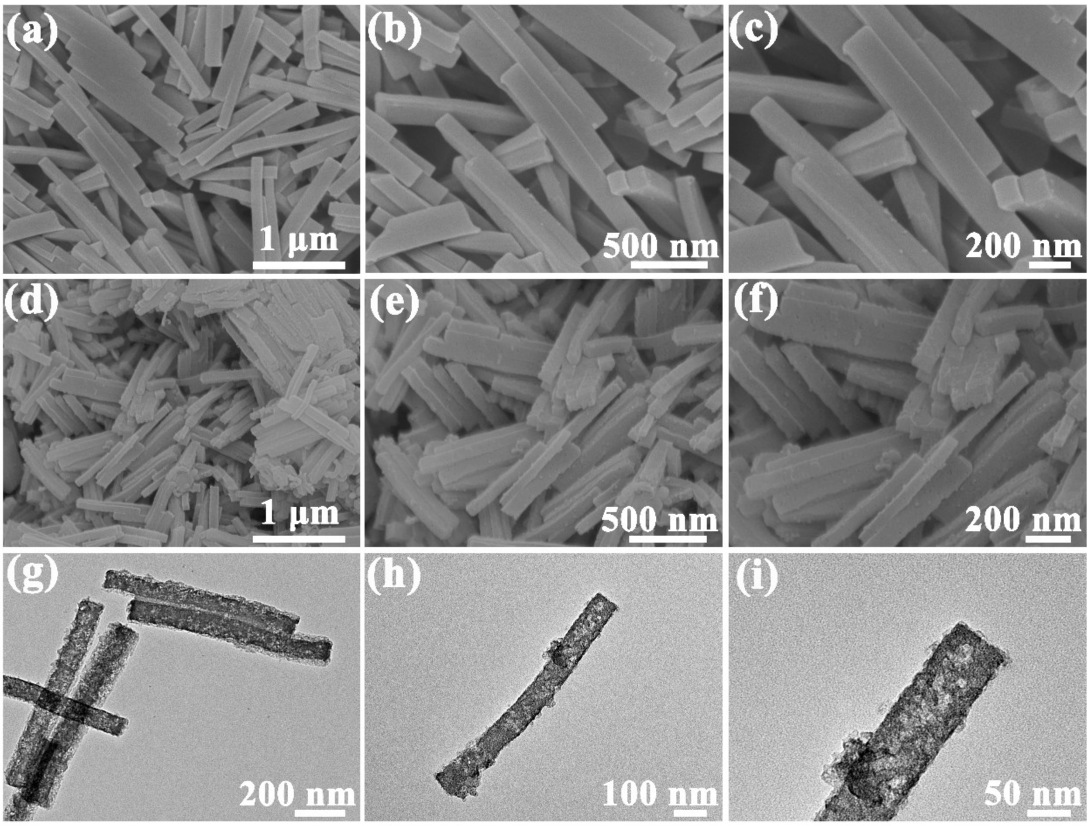

Figure S4. SEM images of (a, b, c) 5Fe-ZIF-NR and (d, e, f) 5Fe- N/C-NR; TEM images of (g, h, i) 5Fe-N/C-NR.

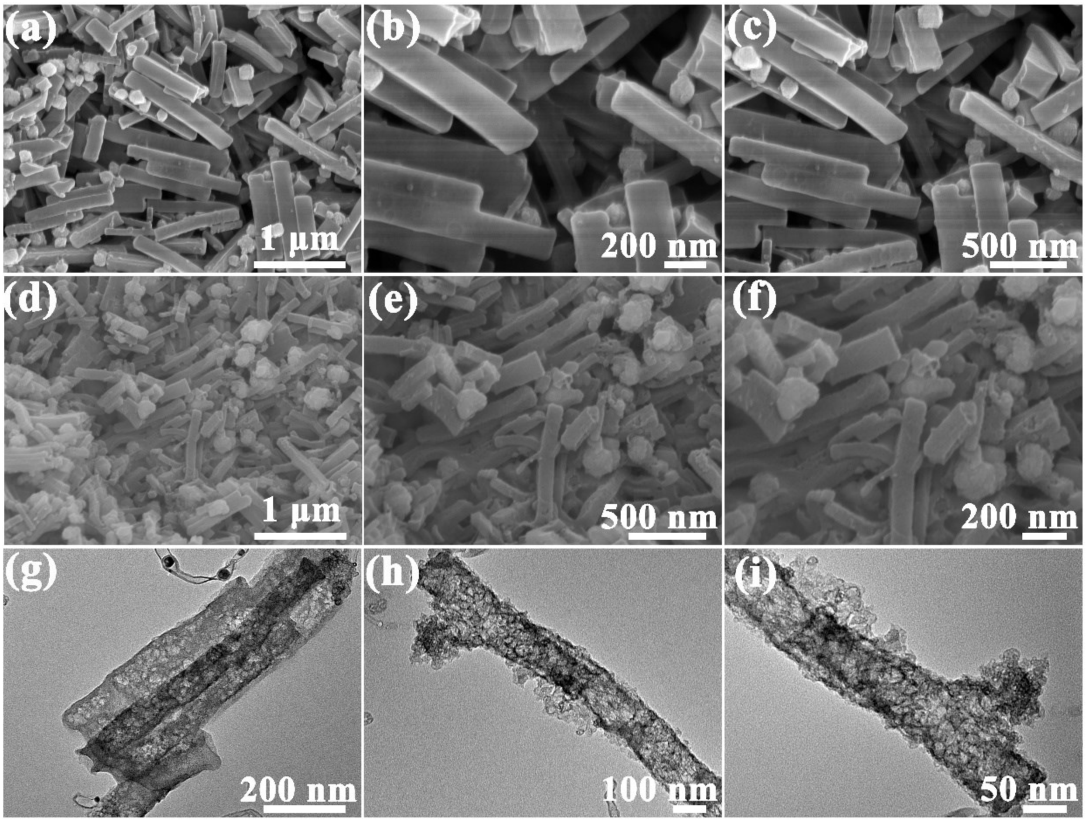

Figure S5. SEM images of (a, b, c) 7Fe-ZIF-NR and (d, e, f) 7Fe- N/C-NR; TEM images of (g, h, i) 7Fe-N/C-NR.

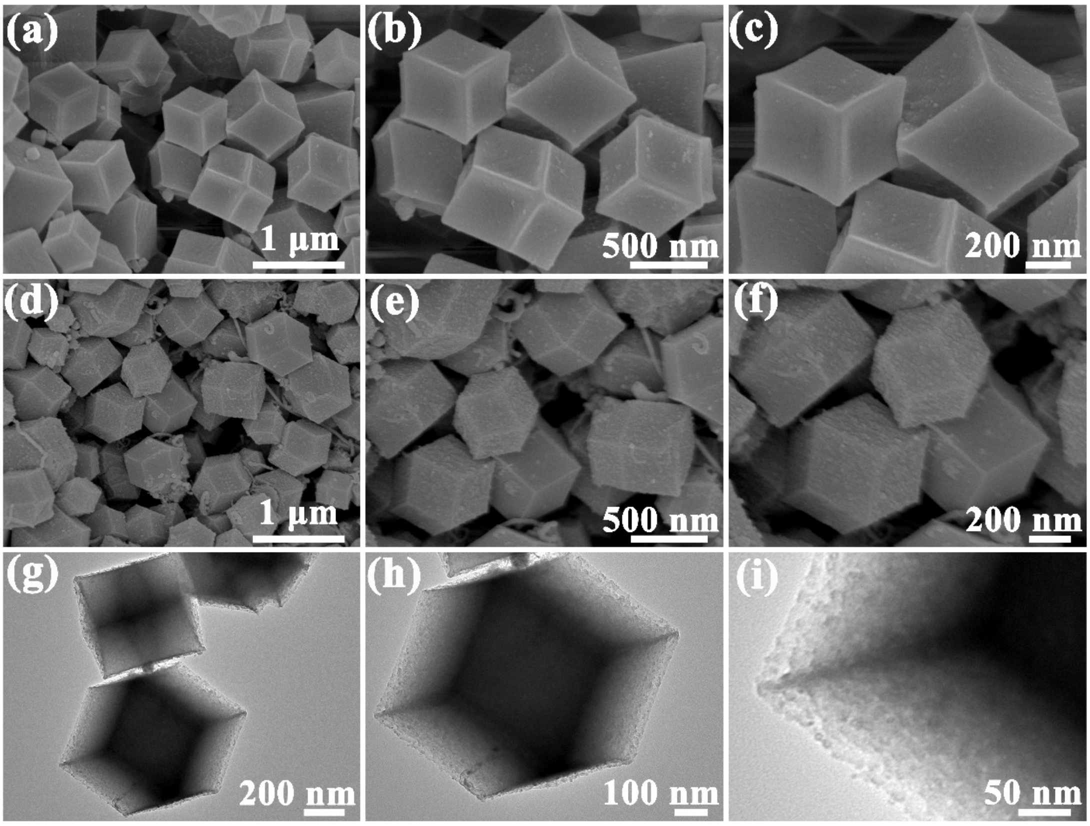

Figure S6. SEM images of (a, b, c) 5Fe-ZIF-RD and (d, e, f) 5Fe- N/C-RD; TEM images of (g, h, i) 5Fe-N/C-RD.

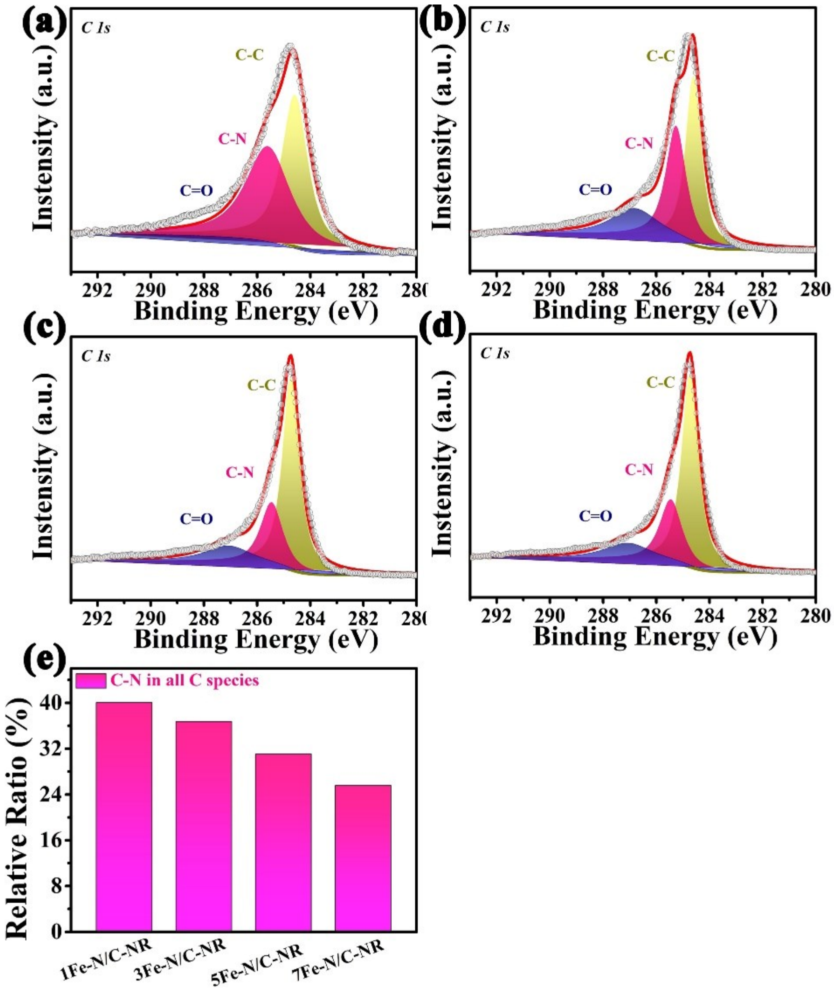

Figure S7. C 1s XPS spectra of (a) 1Fe-N/C-NR, (b) 3Fe-N/C-NR, (c) 5Fe-N/C-NR and (d) 7Fe-N/C-NR. (e) The contents of C–N in all C species (C–C, C–N and C=O) for all samples.

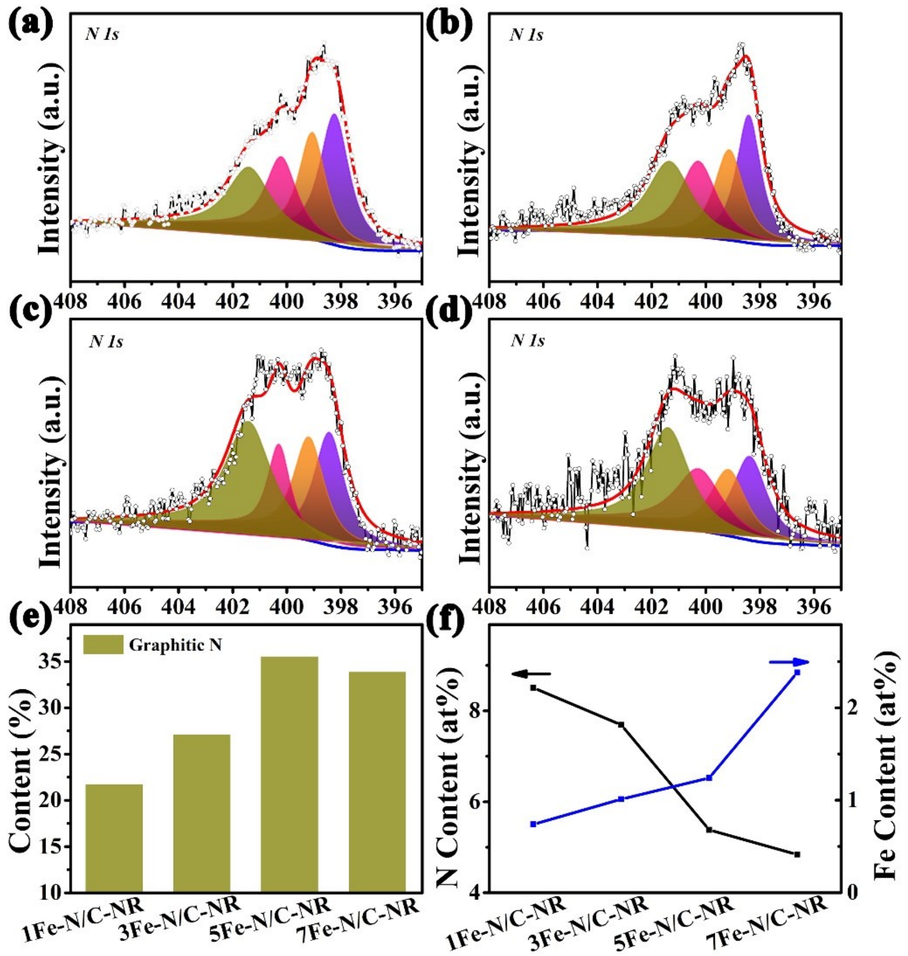

Figure S8. N 1s XPS spectra of (a) 1Fe-N/C-NR, (b) 3Fe-N/C-NR, (c) 5Fe-N/C-NR and (d) 7Fe-N/C-NR. (e) The contents of graphitic N in all N species (pyridinic N, pyrrolic N, N–Fe and graphitic N) for all samples. (f) Influence of iron doping on the N and Fe contents of various catalysts based on XPS analysis.

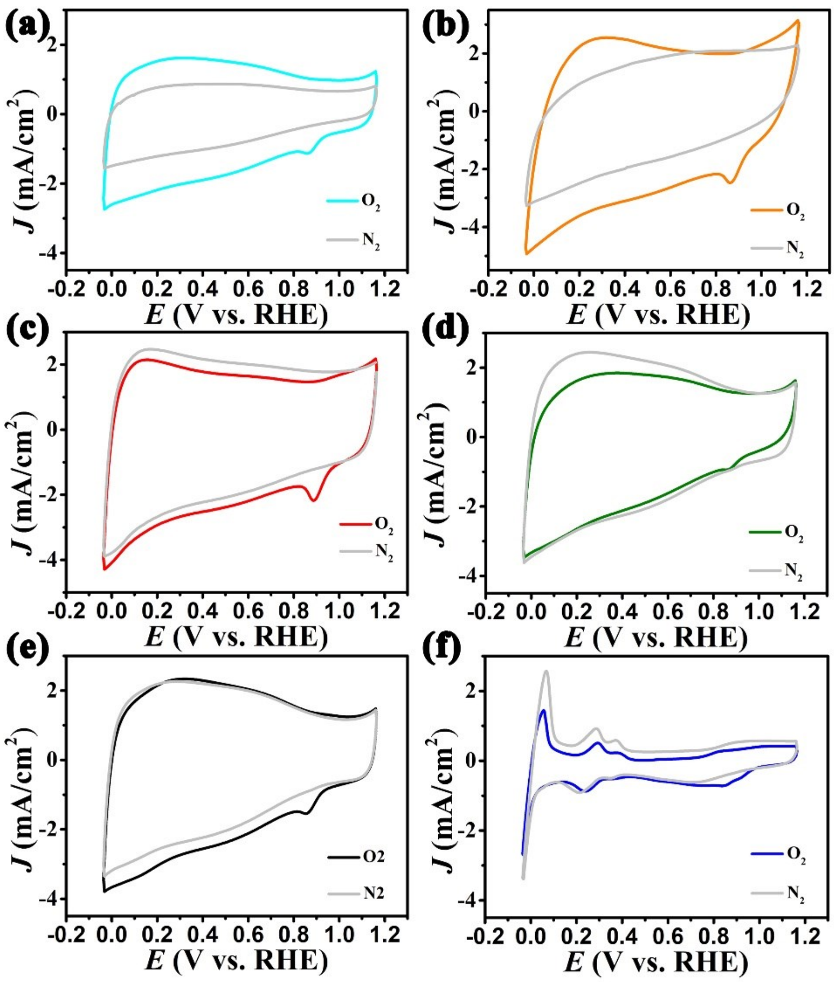

Figure S9. CV curves of (a) 1Fe-N/C-NR, (b) 3Fe-N/C-NR, (c) 5Fe-N/C-NR, (d) 7Fe-N/C-NR, (e) 5Fe-N/C-RD and (f) Pt/C in N_2-saturated and O_2-saturated 0.1 M KOH solution.

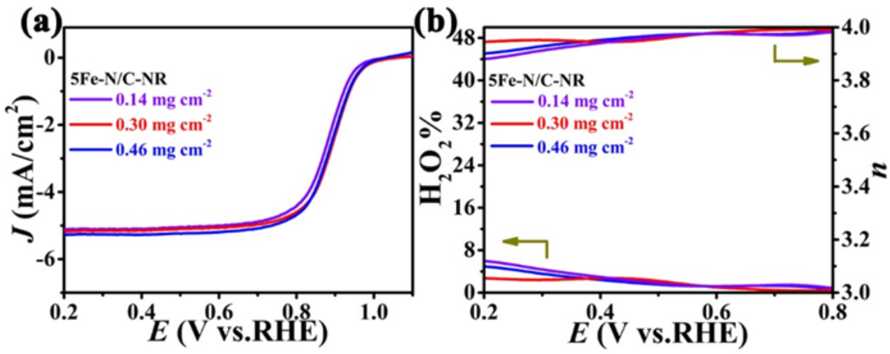

Figure S10. (a) LSV curves and (b) electron-transfer numbers and H_2O_2 yields for various 5Fe-N/C-NR catalyst loadings, at 1600 rpm in 0.1 M KOH electrolyte.

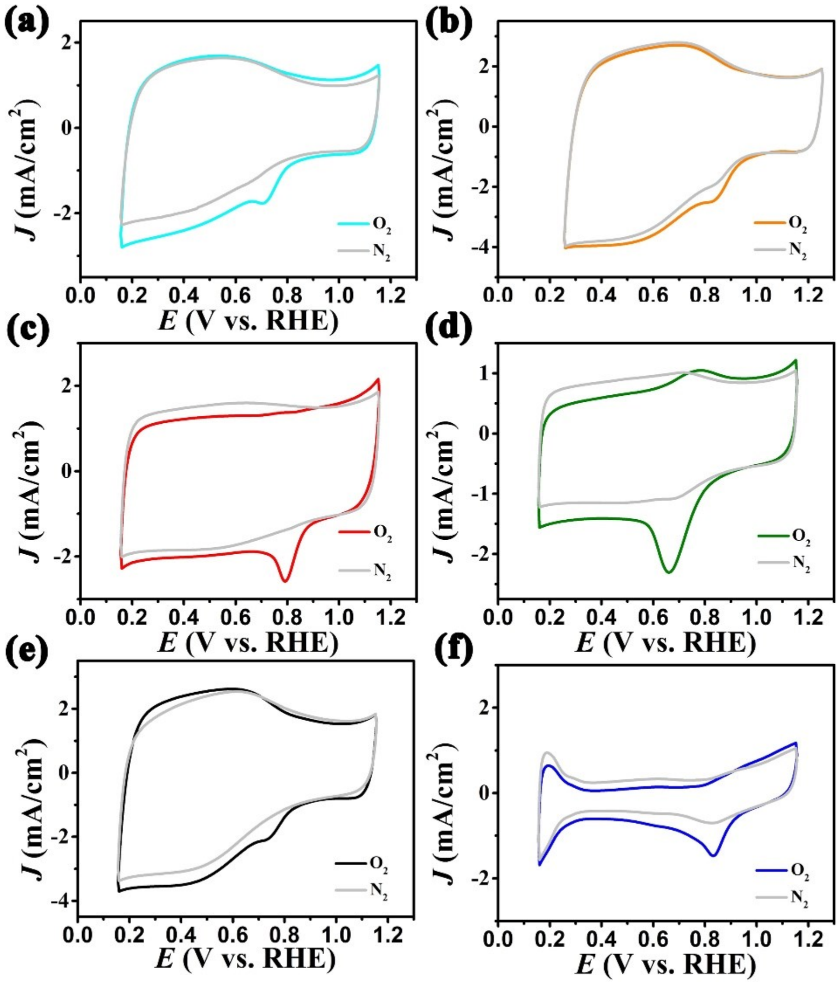

Figure S11. CV curves of (a) 1Fe-N/C-NR, (b) 3Fe-N/C-NR, (c) 5Fe-N/C-NR, (d) 7Fe-N/C-NR, (e) 5Fe-N/C-RD and (f) Pt/C in N_2-saturated and O_2-saturated 0.1 M $HClO_4$ solution.

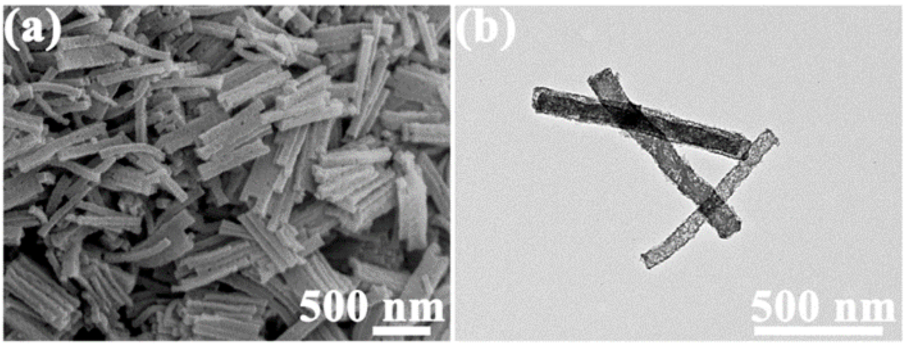

Figure S12. (a) SEM and (b) TEM images of 5Fe-N/C-NR after the stability test in acidic electrolyte.

Table S1. BET surface areas, total pore volumes, miropore volume, meso/macropore volume and element contents of various samples measured by XPS analysis

Samples	S_{BET} (m^2/g)	Total pore volume (cm^3/g)	Miropore volume (cm^3/g)	Meso/macropore volume (cm^3/g)	Element contents (at. %)		
					C	N	Fe
N/C	939	0.59	0.44	0.15	-	-	-
1Fe-N/C-NR	819	0.50	0.39	0.11	81.75	8.51	0.74
3Fe-N/C-NR	612	0.48	0.29	0.19	81.77	7.69	1.01
5Fe-N/C-NR	502	0.44	0.24	0.20	80.86	5.38	1.24
7Fe-N/C-NR	379	0.44	0.19	0.25	80.80	4.84	2.38

Table S2. The contents of different types of C and N for various samples form XPS analysis.

Samples	C type			N type			
	C–C(%)	C–N(%)	C=O(%)	Pyridinic N(%)	N–Fe (%)	Pyrrolic N(%)	Graphitic N(%)
1Fe-N/C-NR	38.20	40.05	21.75	33.28	24.95	20.14	21.63
3Fe-N/C-NR	42.85	36.73	20.42	26.79	22.65	23.52	27.04
5Fe-N/C-NR	46.48	31.04	22.48	25.54	22.46	15.07	36.93
7Fe-N/C-NR	60.41	25.57	14.02	14.85	22.14	27.52	35.49

Table S3. Comparison of the onset potentials and the half-wave potentials toward ORR for literature-reported Fe-based catalysts and 5Fe-N/C-NR from this work under alkaline conditions.

Electrocatalysts	E_{onset} (V vs. RHE)	$E_{1/2}$ (V vs. RHE)	Electrolyte	References
Fe-SAC/NC	0.95	0.84	0.1 M KOH	[1]
Fe-CZIF-800-10	0.982	0.830	0.1 M KOH	[2]
Fe,N-HPCC	0.972	0.898	0.1 M KOH	[3]
Fe_{14}NDC-9	0.968	0.888	0.1 M KOH	[4]
Fe(1,10-phen)/KB	0.966	0.861	0.1 M KOH	[5]
Fe-N-HPC-AH	0.97	0.87	0.1 M KOH	[6]
Fe/N/C	0.94	0.84	0.1 M KOH	[7]
Fe-N-C	0.971	0.844	0.1 M KOH	[8]
$Fe_{0.5}$-950	0.97	0.89	0.1 M KOH	[9]
Fe SAs-N/C-20	0.97	0.909	0.1 M KOH	[10]
Fe@Aza-PON	0.9	0.839	0.1 M KOH	[11]
SA-Fe-HPC	0.96	0.89	0.1 M KOH	[12]
$F_{0.2}N_{0.2}M_{0.2}$-900	0.970	0.873	0.1 M KOH	[13]
FeCo	0.995	0.920	0.1 M KOH	[14]
(Fe,Co)/N-C	1.06	0.863	0.1 M KOH	[15]
Fe/N/S-CNTs	0.987	0.887	0.1 M KOH	[16]
FeSAs/PTF-600	1.01	0.87	0.1 M KOH	[17]
CA-Fe/MF-N900	0.98	0.83	0.1 M KOH	[18]
Fe/N/S-PCNT	0.96	0.84	0.1 M KOH	[19]
C-FeZIF-900-0.84	0.95	0.84	0.1 M KOH	[20]
Fe/N/C-1000-2	1.0	0.87	0.1 M KOH	[21]
Fe_3-NG	0.965	0.826	0.1 M KOH	[22]
Fe_3C@NG-800-0.2	0.98	0.83	0.1 M KOH	[23]
S-Fe/N/C	0.91	0.84	0.1 M KOH	[24]

Fe_3C@N-CNT	0.97	0.85	0.1 M KOH	[25]
Fe-N-CC	0.94	0.83	0.1 M KOH	[26]
Fe-N-CNFs	0.93	0.82	0.1 M KOH	[27]
6%Fe-N-S CNN	0.91	0.85	0.1 M KOH	[28]
FeN_x-CN/g-GEL	1.0	0.9	0.1 M KOH	[29]
C-ZIF/LFP	0.98	0.88	0.1 M KOH	[30]
Fe-Fe_3C@Fe-N-C	0.97	0.88	0.1 M KOH	[31]
C-FeZIF-1.44-950	0.99	0.864	0.1 M KOH	[32]
FeNC-1000	0.99	0.90	0.1 M KOH	[33]
C−$Fe(OH)_3$@ZIF-1000	0.99	0.88	0.1 M KOH	[34]
Fe2-Z8-C	0.985	0.871	0.1 M KOH	[35]
Fe-N-C-3	0.91	0.805	0.1 M KOH	[36]
Cu@Fe-N-C	1.01	0.892	0.1 M KOH	[37]
mC-TpBpy-Fe	0.92	0.845	0.1 M KOH	[38]
Fe,Co,N-CNP(0.3)	0.979	0.875	0.1 M KOH	[39]
FeNC-20-1000	1.040	0.88	0.1 M KOH	[40]
CPM-99Fe/C	0.95	0.802	0.1 M KOH	[41]
Fe(0)@FeNC	0.946	0.852	0.1 M KOH	[42]
NiFe-N/C	0.99	0.81	0.1 M KOH	[43]
S/N_Fe_{27}	0.93	0.87	0.1 M KOH	[44]
$Fe_{0.5}Co_{0.5}$Pc-CP	0.937	0.848	0.1 M KOH	[45]
FePcZnPor-CMP	0.936	0.866	0.1 M KOH	[46]
FePhenMOF-ArNH_3	0.98	0.78	0.1 M KOH	[47]
Fe NS–PC-800	0.95	0.85	0.1 M KOH	[48]
NFe/CNs-700	0.937	0.863	0.1 M KOH	[49]
COP-TPP(Fe)@MOF-900	0.99	0.828	0.1 M KOH	[50]
$Fe_{0.3}Co_{0.7}$/NC cages	0.98	0.88	0.1 M KOH	[51]
Fe-NMCSs	1.03	0.86	0.1 M KOH	[52]
5Fe-N/C-NR	1.01	0.90	0.1 M KOH	This work

Pt/C	0.95	0.86	0.1 M KOH	This work

E_{onset}: Onset potential; $E_{1/2}$: Half-wave potential

Table S4. Comparison of the onset potentials and the half-wave potentials toward ORR for literature-reported Fe-based catalysts and 5Fe-N/C-NR from this work under acidic conditions.

Electrocatalysts	E_{onset} (V vs. RHE)	$E_{1/2}$ (V vs. RHE)	Electrolyte	References
Fe-SAC/NC	0.80	0.69	0.5 M H_2SO_4	[1]
Fe-N-HPCC	-	0.76	0.1 M $HClO_4$	[3]
Fe-N-C	-	0.657	0.1 M $HClO_4$	[8]
Fe-N-C-950	0.92	0.78	0.1 M $HClO_4$	[53]
Meso-Fe–N–C/N–G	0.83	0.72	0.1 M $HClO_4$	[54]
Fe_{SA}-N-C	0.93	0.78	0.1 M $HClO_4$	[55]
AT-BP-E	-	0.78	0.1 M $HClO_4$	[56]
Fe_1-N-NG/RGO	0.96	0.84	0.1 M $HClO_4$	[57]
FeNC-1000	0.89	0.80	0.5 M H_2SO_4	[33]
f-FeCoNC	0.87	0.81	0.1 M $HClO_4$	[58]
1MIL/40ZIF-1000	0.83	0.79	0.5 M H_2SO_4	[31]
C-$FeHZ_8$@g-C_3N_4-950	0.90	0.78	0.1 M $HClO_4$	[59]
5Fe-N/C-NR	0.94	0.81	0.1 M $HClO_4$	This work
Pt/C	0.94	0.81	0.1 M $HClO_4$	This work

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