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

Supplementary Information:

Nitrogen-Self-doped carbon with porous graphene-like structures as a highly efficient catalyst for oxygen reduction

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Figure S1

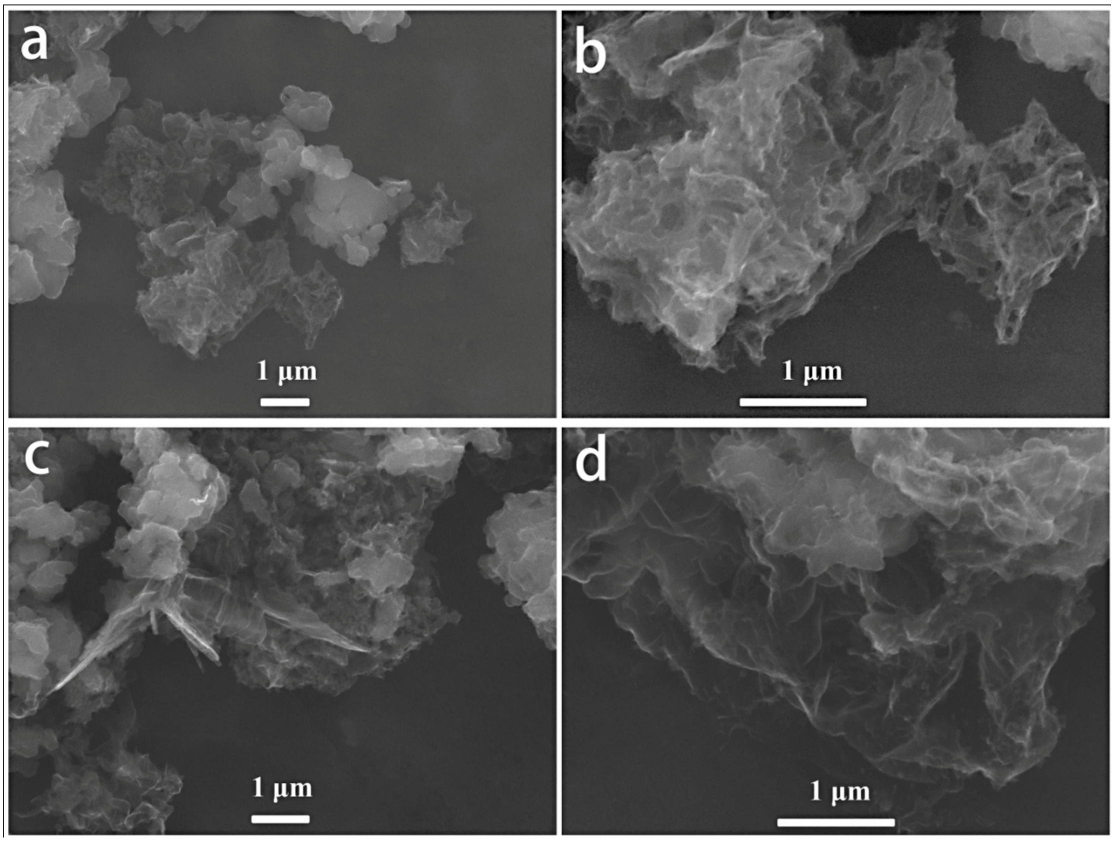


Figure S2

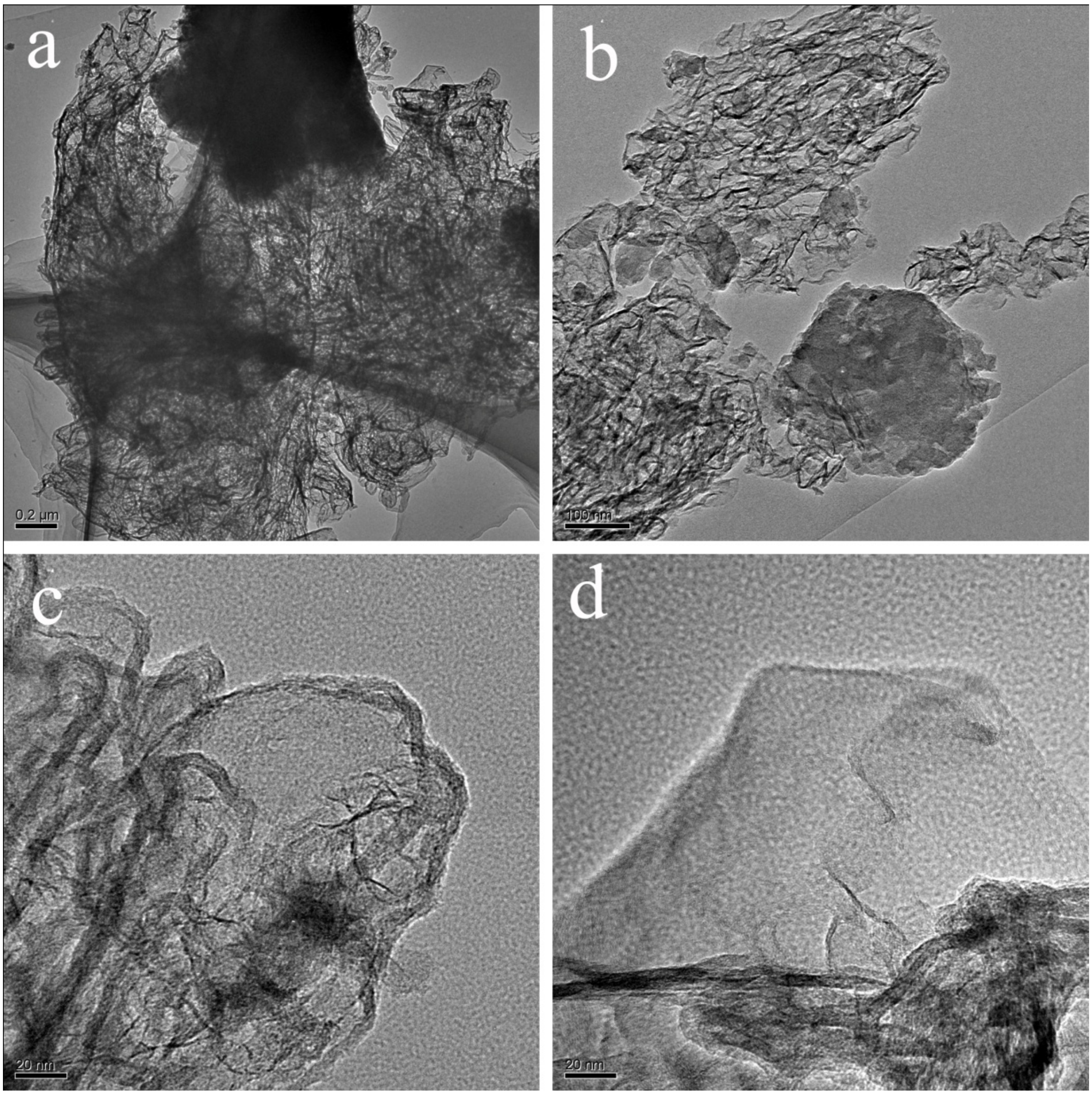


Figure S3

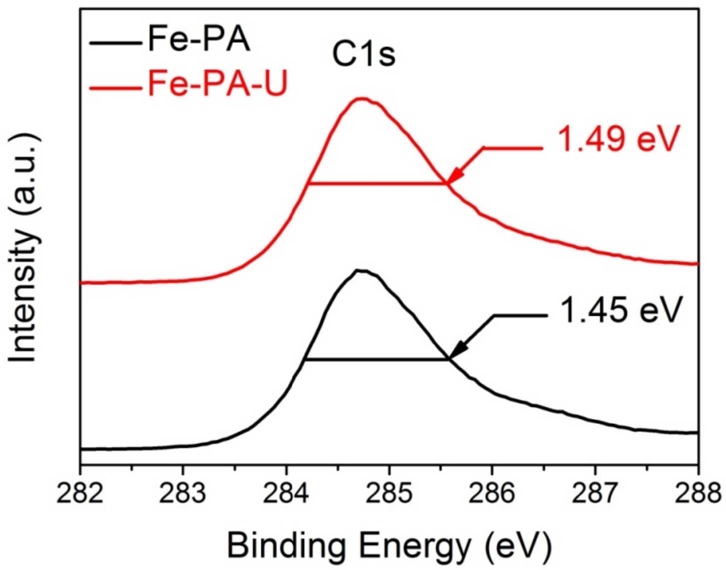


Figure S4

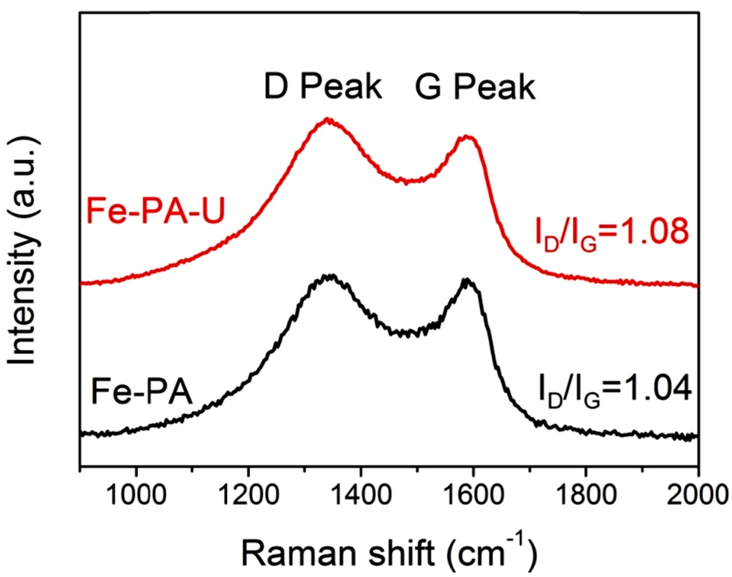


Figure S5

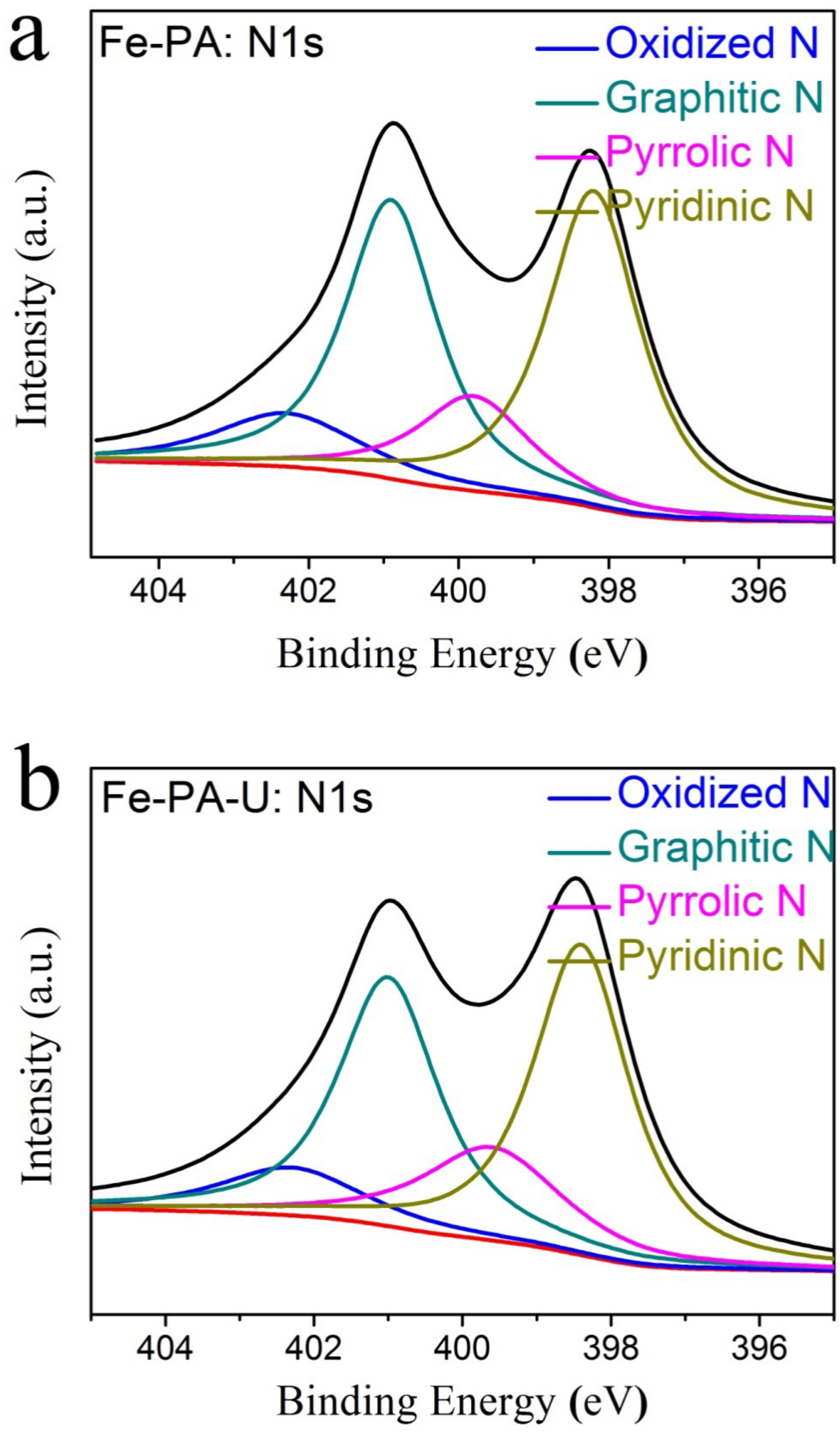

a
Fe-PA: N1s
Oxidized N
Graphitic N
Pyrrolic N
Pyridinic N
Intensity (a.u.)
404
402
400
398
396
Binding Energy (eV)
b
Fe-PA-U: N1s
Oxidized N
Graphitic N
Pyrrolic N
Pyridinic N
Intensity (a.u.)
404
402
400
398
396
Binding Energy (eV)

Table S1

Sample	Content (%)				Content of N species (%)			
	C	N	O	Fe	Oxidized	Graphitic	Pyrrolic	Pyridinic
Fe-PVP	83.06	3.08	13.6	0.26	0.320	1.08	0.445	1.24
Fe-PVP-U	84.54	5.63	9.40	0.43	0.516	1.87	0.983	2.26

Figure S6

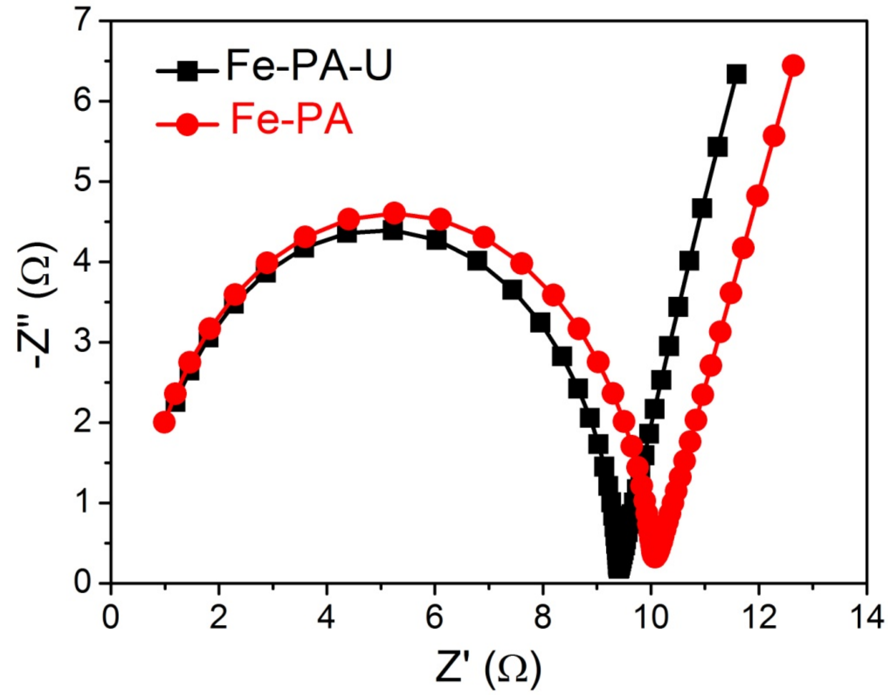
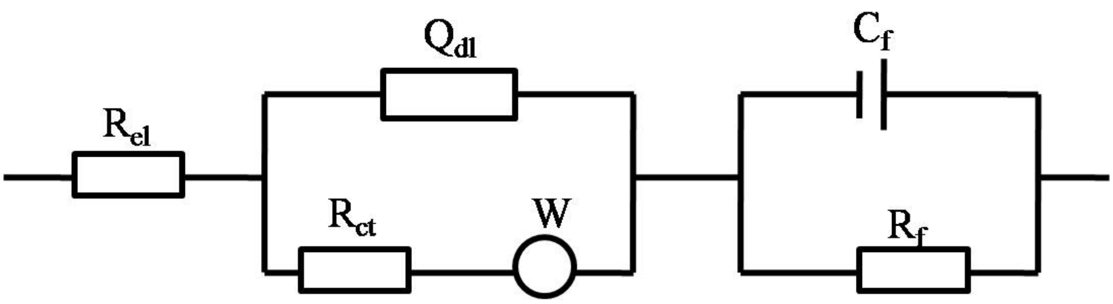


Figure S7



The equivalent circuit, where R_{el} is solution resistance, R_{ct} is charge transfer resistance, W is Warburg element, Q_{dl} is double layer capacitance, R_f is film resistance, C_f is film capacitance.

Table S2

Catalyst	**Template**	**E_{onset} (V) / relative to Pt/C**	**$E_{1/2}$ (V) / relative to Pt/C**	**Reference electrode**	**Medium**	**Ref.**
Fe-PA-U	-	-0.08 V / -50 mV	-0.24 V / -100 mV	SCE	0.1 M KOH at 1600 rpm	this work
P-Z8-Te-1000	silica colloid	0.93 V / -20 mV	0.85 V / 0 mV	RHE	0.1 M KOH at 1600 rpm	1
N-Fe-MOF	MOF	1.02 V / 0 mV	0.88 V / ca. +10 mV	RHE	0.1 M KOH at 1600 rpm	2
N-doped Fe/Fe3C@C/RGO	MOF	0.99 V / ca. 0 mV	0.92 V / ca. -10 mV	RHE	0.1 M KOH at 1600 rpm	3
Carbon-S	ZIF-7	0.844 V / -80 mV	0.678 V / ca. -110 mV	RHE	0.1 M KOH at 1600 rpm	4
SN/C-900	Nano silica spheres	0.03 V / -10 mV	-0.25 V / ca. -50 mV	Ag/AgCl	0.1 M KOH at 1600 rpm	5
NPS-C-M	MOF	-0.006 V /	-0.24 V /	Ag/AgCl	0.1 M KOH	6

OF-5		-36 mV	ca. -50 mV		at 1600 rpm	
NC900	ZIF-8	0.83 V / ca. -100 mV	-	RHE	0.1 M KOH at 1600 rpm	7
PANI-4.5 Fe-HT2(SBA-15)	SBA-15	0.95 V / -40 mV	0.84 V / +10 mV	RHE	0.1 M KOH at 1600 rpm	8
N-PANn-1000	AAO	-0.05 V / -20 mV	-/ -	Ag/AgCl	0.1 M KOH at 1600 rpm	9
NS(3 : 1)–C-MOF-5	MOF	-0.005 V / -5 mV	-/-	Ag/AgCl	0.1 M KOH at 1600 rpm	10
ZIF-67-900-AL	ZIF-67	0.94V / -40 mV	-/-	RHE	0.1 M KOH at 1600 rpm	11

E_0: onset potential, $E_{1/2}$: half-wave potential, MOF: metal−organic framework, ZIF: zeolitic imidazolate frameworks, SBA: ordered mesoporous silica, AAO: Anodic alumina oxide.

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The Koutecky-Levich (K-L) equation

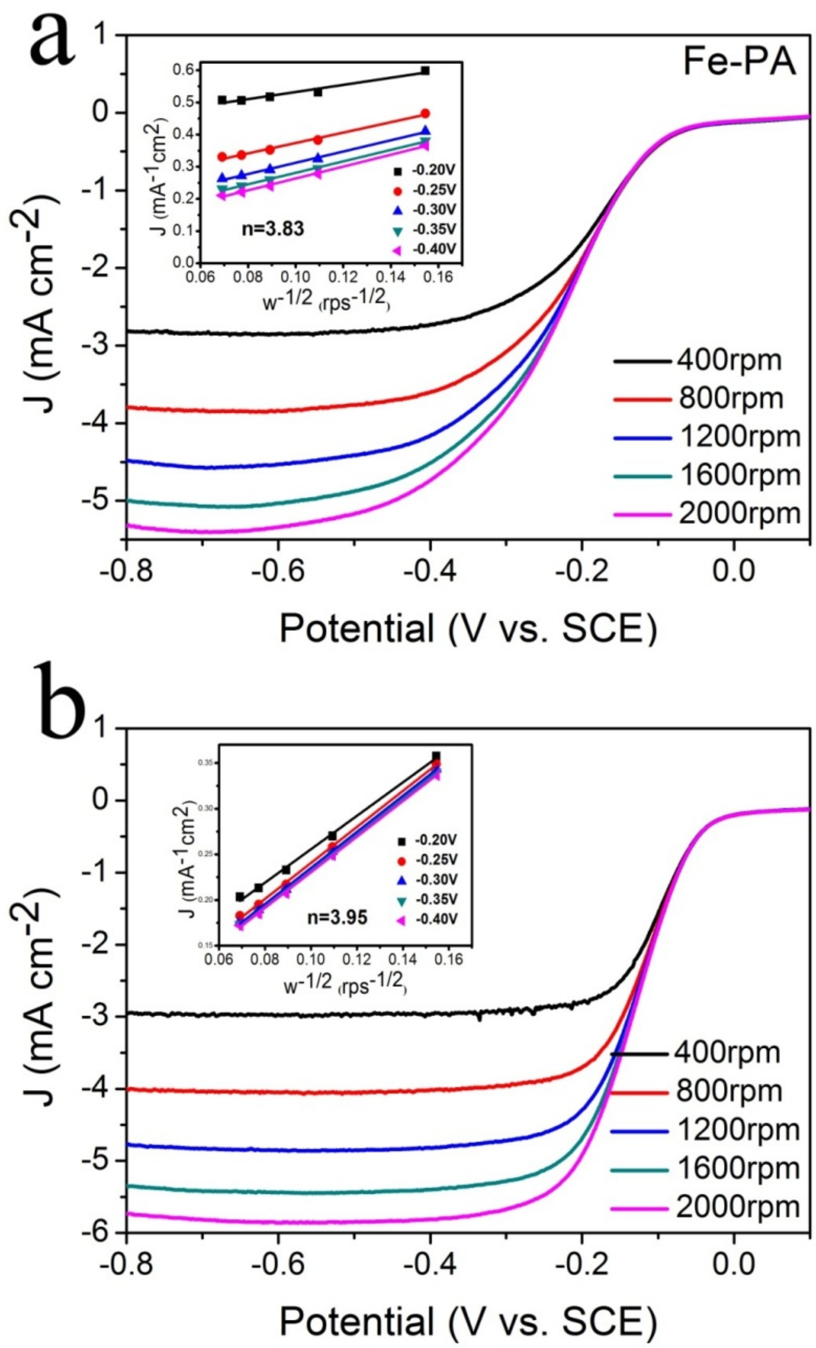
The K–L equation as given below:

$$\frac{1}{J}=\frac{1}{J_L}+\frac{1}{J_K}=\frac{1}{B\omega^{1/2}}+\frac{1}{J_K} \tag{1}$$

$$B=0.62\mathrm{n}FC_0(D_0)^{2/3}\upsilon^{-1/6} \tag{2}$$

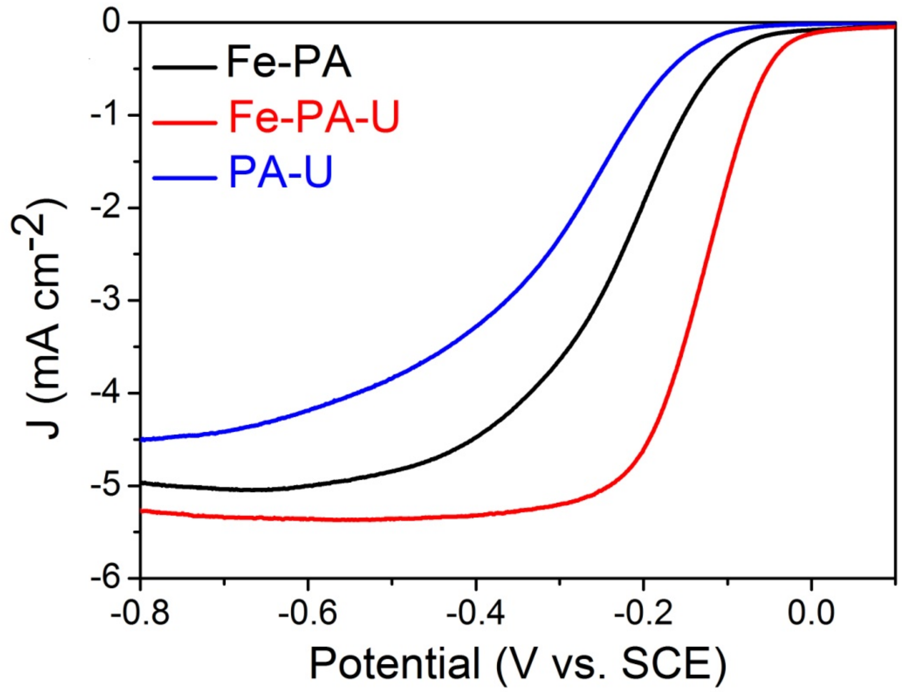
where J denotes the measured current density, J_K is the kinetic current density, J_L is the diffusion-limited current density, ω is the electrode rotation rate, F is the Faraday constant (96485 C mol^{-1}), C_0 is the bulk concentration of O_2 (1.2×10^{-3} mol L^{-1}), D_0 is the diffusion coefficient of O_2 (1.9×10^{-5} cm^2 s^{-1}) and v is the kinetic viscosity of the electrolyte (1.0×10^{-2} cm^2 s^{-1}).

Figure S8



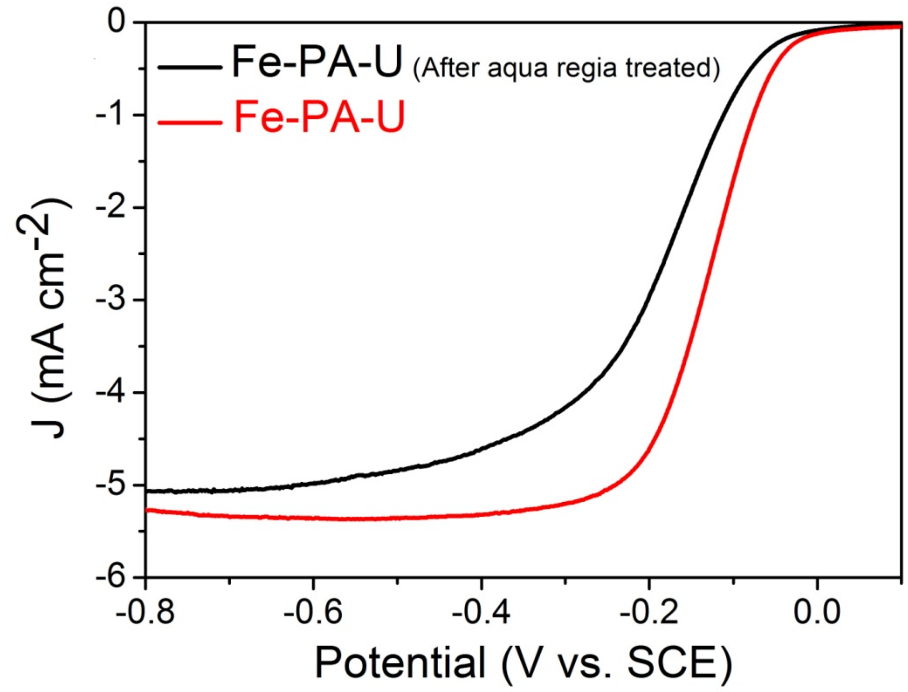
a
Fe-PA
J (mA cm-2)
Potential (V vs. SCE)
400rpm
800rpm
1200rpm
1600rpm
2000rpm
J (mA-1cm2)
w-1/2 (rps-1/2)
-0.20V
-0.25V
-0.30V
-0.35V
-0.40V
n=3.83
b
J (mA cm-2)
Potential (V vs. SCE)
400rpm
800rpm
1200rpm
1600rpm
2000rpm
J (mA-1cm2)
w-1/2 (rps-1/2)
-0.20V
-0.25V
-0.30V
-0.35V
-0.40V
n=3.95

Figure S9



Fe-PA
Fe-PA-U
PA-U
J (mA cm-2)
Potential (V vs. SCE)
0
-1
-2
-3
-4
-5
-6
-0.8
-0.6
-0.4
-0.2
0.0

Figure S10


Fe-PA-U (After aqua regia treated)
Fe-PA-U
J (mA cm-2)
Potential (V vs. SCE)
0
-1
-2
-3
-4
-5
-6
-0.8
-0.6
-0.4
-0.2
0.0