Supporting Information

Highly dispersed Ir/Fe nanoparticles anchored at nitrogen-doped activated pyrolytic carbon black as high-performance OER catalyst for lead recovery

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Fig. S1. The mapping image of N element in IrFe/NCBp.

Fig. S2. The C 1s XPS spectra of IrFe/CBp, IrFe/ACBp and IrFe/NCBp.

Fig. S3. The N 1s XPS spectra of NCBp and IrFe/NCBp.

Fig. S4. The XRD patterns of CBp, ACBp and NCBp.

Fig. S5. TEM images of (a) IrFe/ACBp and (b) IrFe/NCBp.

Fig. S6. The LSV curves of CBp, ACBp and NCBp at 2 mV s^{-1}.

Fig. S7. The CV curves with 1.14-1.24 V (vs. RHE) potential interval of (a) IrFe/CBp, (b) IrFe/ACBp, (c) IrFe/NCBp and (d) Ir/C.

Fig. S8. Stability test of IrFe/NCBp at 100 mA cm^{-2}.

Fig. S9. (a) TEM image, (b) HRTEM image, (c) XRD pattern, and (d) Ir 4f XPS spectrum of Ir/NCBp.

Fig. S10. (a) LSV curve, (b) Tafel slope, and (c) stability test at 10 mA cm^{-2} of Ir/NCBp.

Fig. S11. (a) LSV curve and (b) Tafel slope of Fe/NCBp.

Fig. S12. (a) CV curves of CP and IrFe/NCBp at 50 ℃, (b) Arrhenius plots of CP and IrFe/NCBp.

Table S1. Details of materials and chemicals.

Preparation of CBp, ACBp and NCBp

Raw pyrolytic carbon black contains a large amount of ash, so it is first required to be treated for higher purity. Specifically, 20 g pyrolytic carbon black powder was added into 200 mL 5 M HCl solution and stirred at 65 ℃ for 4 h, and then filtered, washed and dried. Next, the pyrolytic carbon black treated with HCl was mixed with PFA solution, and stirred at 80 ℃ for 2 h. After the reaction was completed, the product was obtained by filtration, washing and drying, denoted as CBp.

For the preparation of ACBp, 1 g CBp and 4 g KOH were mixed thoroughly, and then transferred to a tube furnace with N_2 atmosphere at 700 ℃ for 1.5 h. The ACBp product was obtained by washing to neutral and drying at 100 ℃ overnight.

For the preparation of NCBp, 400 mg ACBp was added into 200 mL 1 M HCl solution and sonicated for 1 h for complete dispersion. 600 mg aniline and 60 mg o-phenylenediamine were added into the mixture with ice bath and maintained stirring for 1 h. 20 mL 0.32 M ammonium persulfate solution was added dropwise within 1 h, and the reaction continued for 6 h. After finishing, the composite product was obtained by filtering, washing and drying, and then activated by KOH with a mass ratio of 1:1 in a tube furnace with N_2 atmosphere at 700 ℃ for 1.5 h. The NCBp product was obtained by washing for pH=7 and drying at 100 ℃ for 12 h.

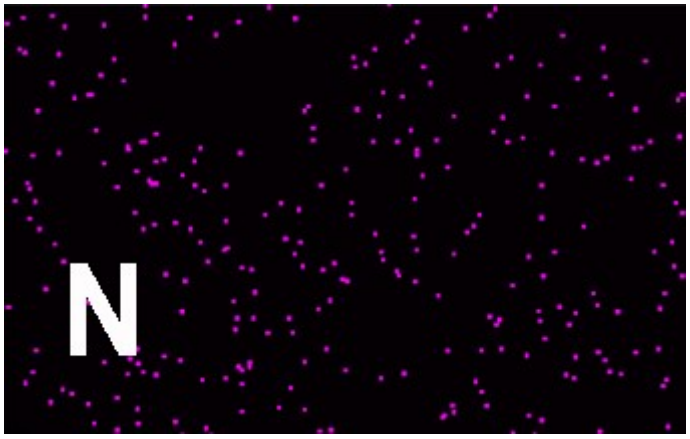

Fig. S1

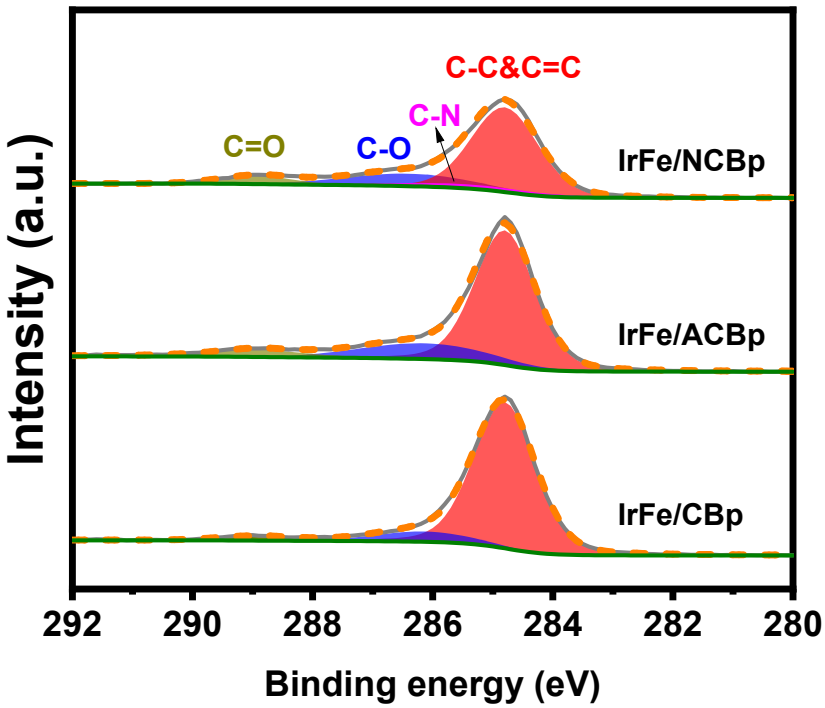
C-C&C=C
C-N
C=O
C-O
IrFe/NCBp
IrFe/ACBp
IrFe/CBp
Intensity (a.u.)
292
290
288
286
284
282
280
Binding energy (eV)

Fig. S2

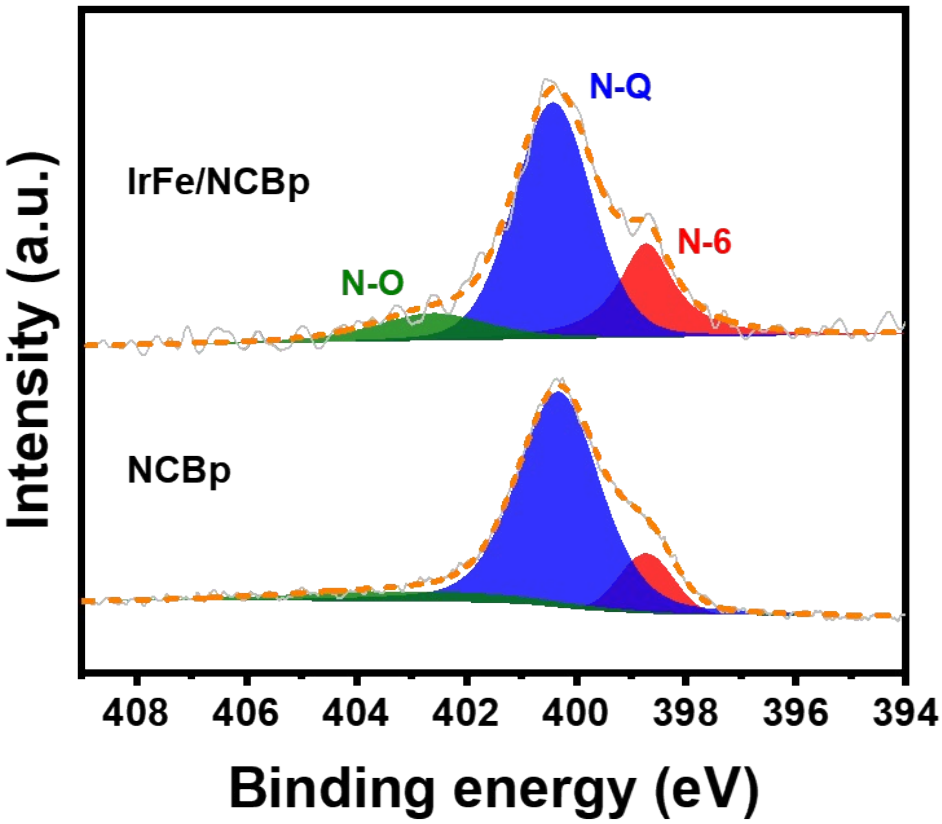
IrFe/NCBp
N-Q
N-6
N-O
NCBp
Intensity (a.u.)
408
406
404
402
400
398
396
394
Binding energy (eV)

Fig. S3

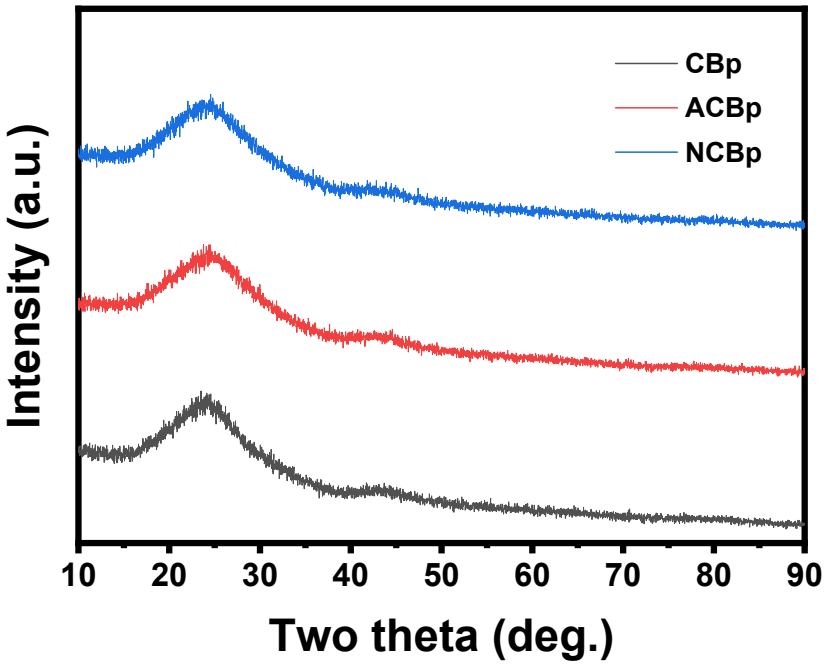
CBp
ACBp
NCBp
Intensity (a.u.)
10
20
30
40
50
60
70
80
90
Two theta (deg.)

Fig. S4

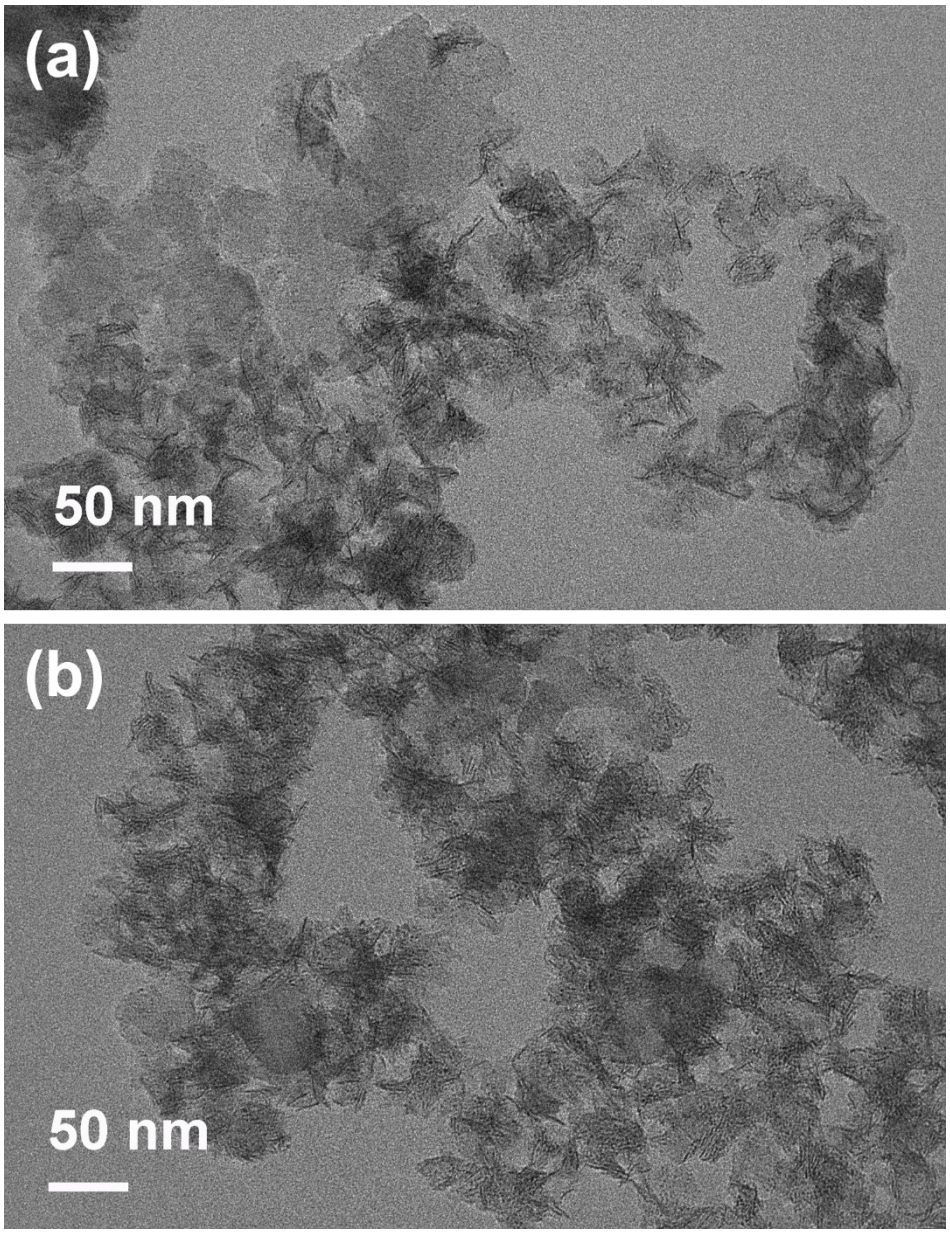

Fig. S5

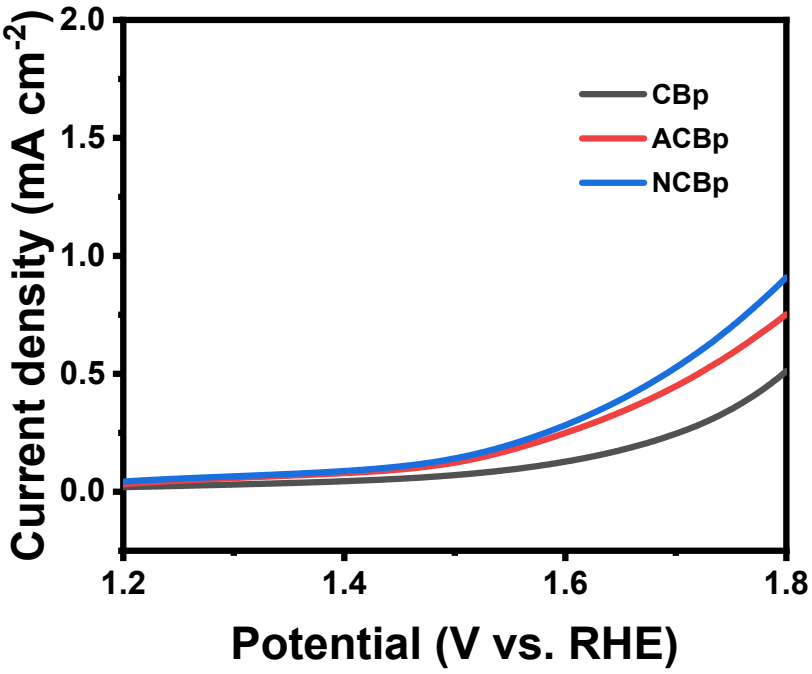
Current density (mA cm-2)
2.0
1.5
1.0
0.5
0.0
1.2
1.4
1.6
1.8
Potential (V vs. RHE)
CBp
ACBp
NCBp

Fig. S6

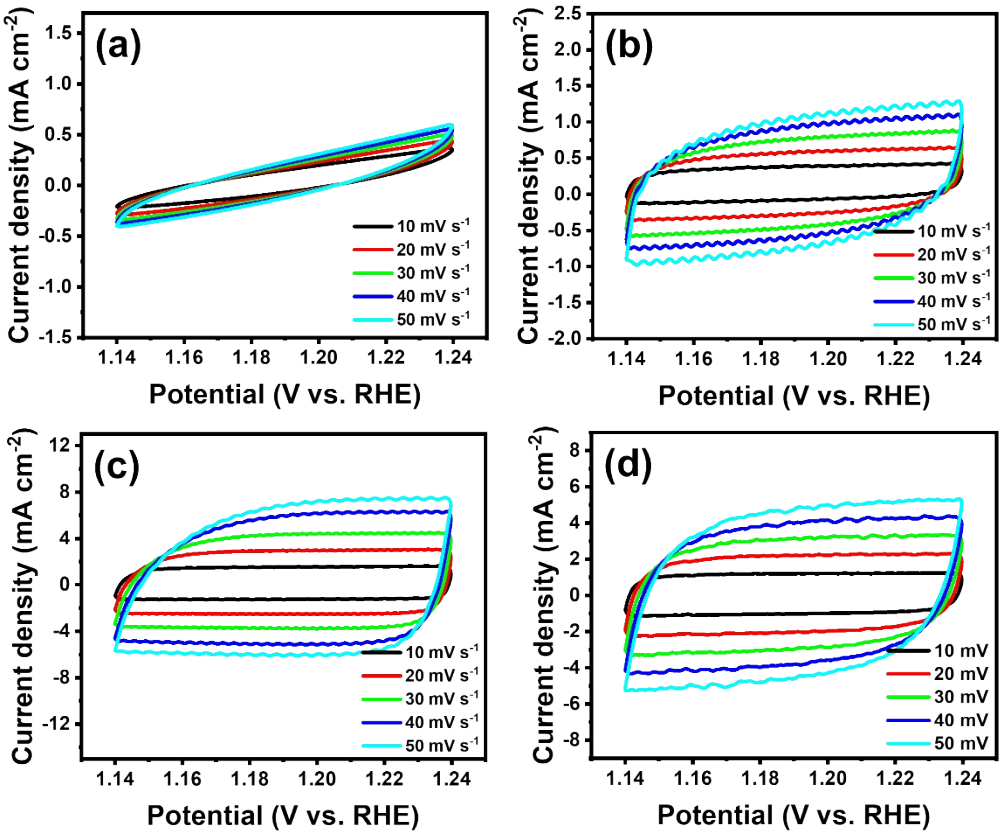
(a)
(b)
(c)
(d)
Current density (mA cm-2)
Potential (V vs. RHE)
10 mV s-1
20 mV s-1
30 mV s-1
40 mV s-1
50 mV s-1
10 mV
20 mV
30 mV
40 mV
50 mV

Fig. S7

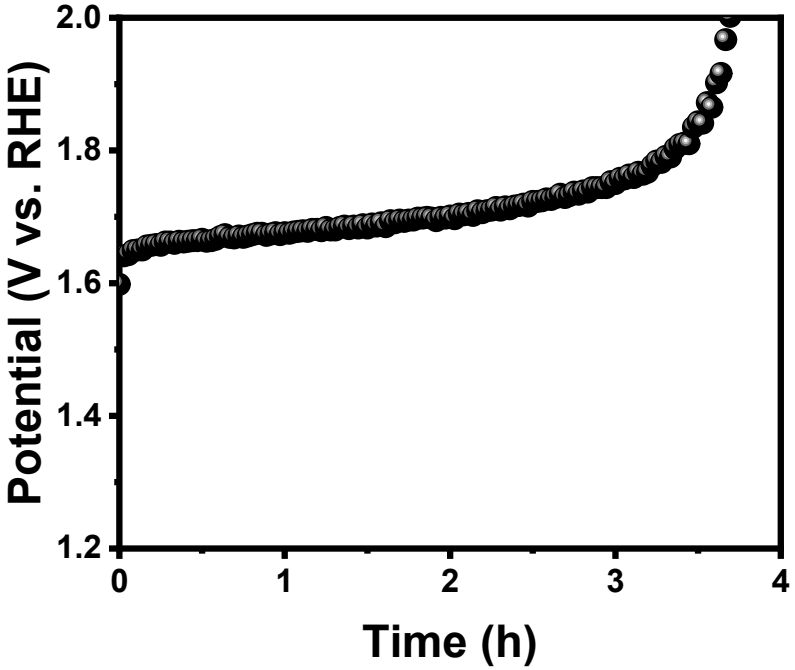

Fig. S8

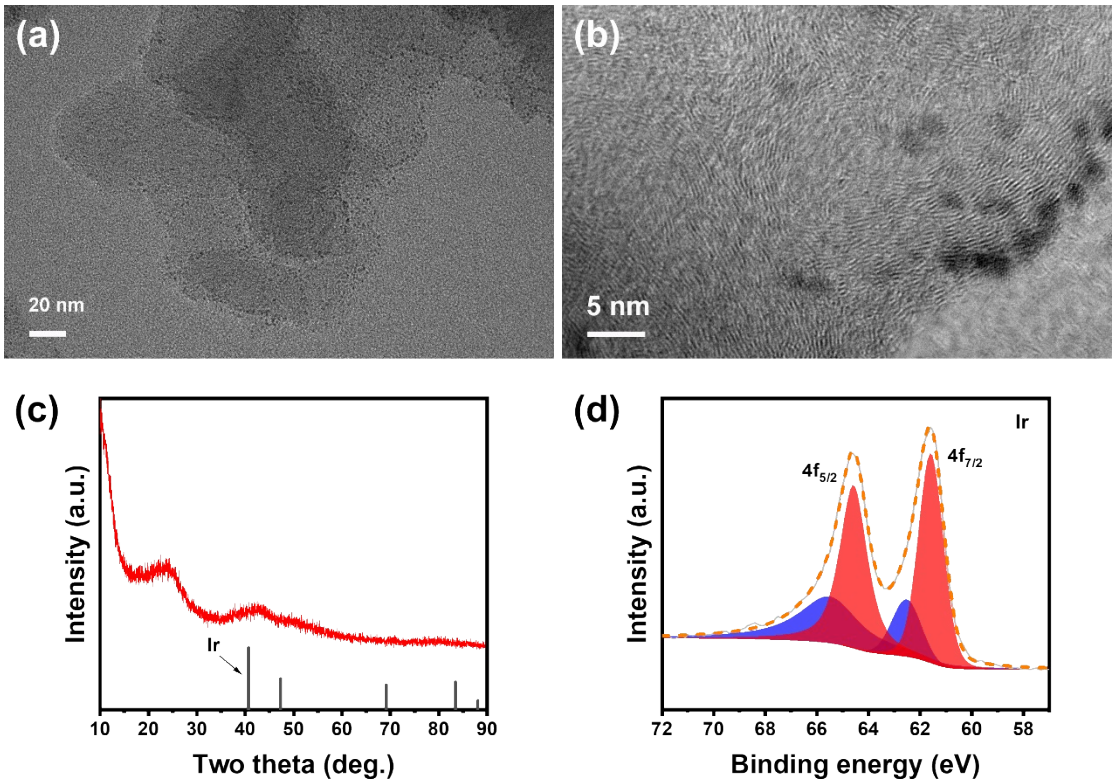
(a)
20 nm
(b)
5 nm
(c)
Intensity (a.u.)
Ir
10 20 30 40 50 60 70 80 90
Two theta (deg.)
(d)
Ir
$4f_{5/2}$
$4f_{7/2}$
Intensity (a.u.)
72 70 68 66 64 62 60 58
Binding energy (eV)

Fig. S9

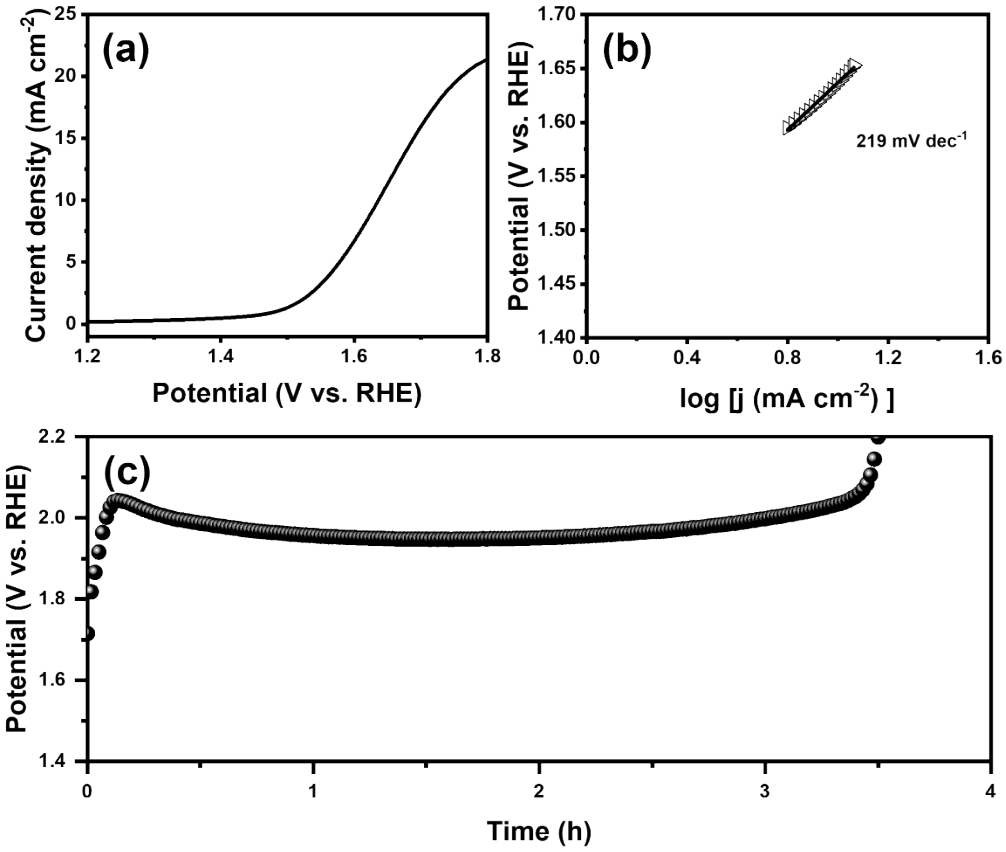
(a)
Current density (mA cm-2)
Potential (V vs. RHE)
(b)
Potential (V vs. RHE)
219 mV dec-1
log [j (mA cm-2)]
(c)
Potential (V vs. RHE)
Time (h)

Fig. S10

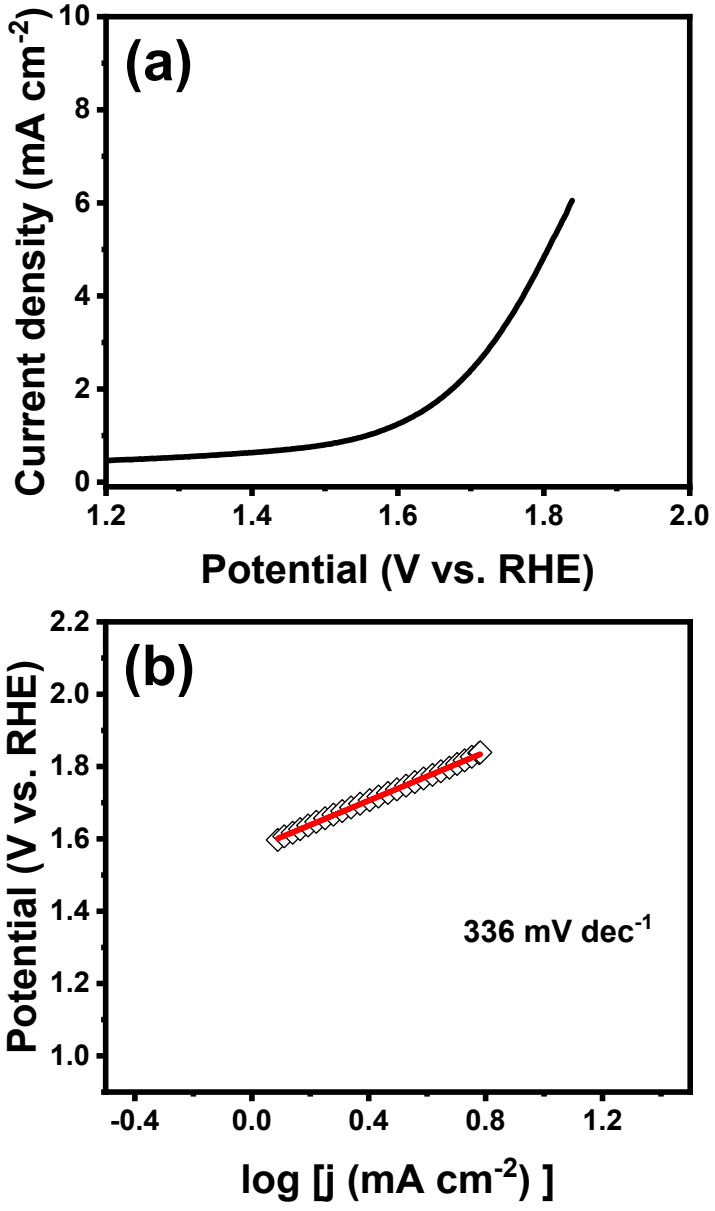
(a)
Current density (mA cm-2)
Potential (V vs. RHE)
(b)
Potential (V vs. RHE)
336 mV dec-1
log [j (mA cm-2)]

Fig. S11

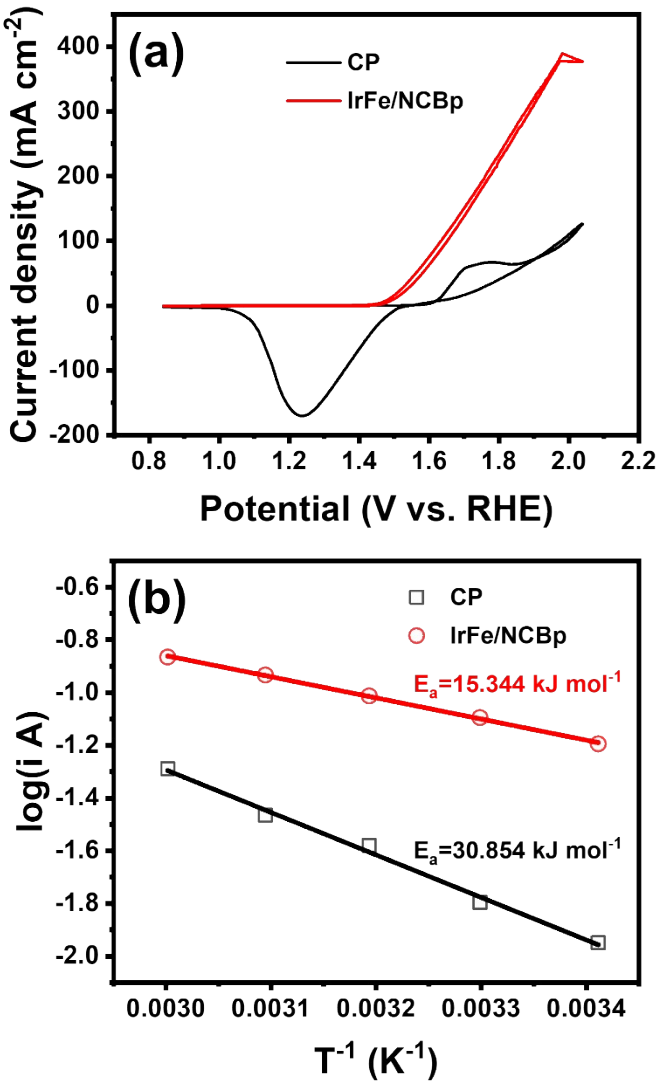
(a)
CP
IrFe/NCBp
Current density (mA cm-2)
400
300
200
100
0
-100
-200
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
Potential (V vs. RHE)
(b)
CP
IrFe/NCBp
Ea=15.344 kJ mol-1
Ea=30.854 kJ mol-1
log(i A)
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
0.0030
0.0031
0.0032
0.0033
0.0034
T-1 (K-1)

Fig. S12

Table S1. Details of materials and chemicals.

Materials and reagents	Manufacturers
Pyrolytic carbon black	China Westlake Holdings
Hydrochloric acid (HCl, 36–38%)	Beijing Chemicals Works
PFA solution	Henan Haoda Industrial Co., Ltd.
Ammonium persulfate ($(NH_4)_2S_2O_8$, AR)	Tianjin Fuchen Chemical Reagent Co., Ltd.
Aniline	Tianjin Fuchen Chemical Reagent Co., Ltd.
O-phenylenediamine	Beijing chemicals works
Potassium hydroxide (KOH, 95%)	Beijing chemicals works
Iridium tetrachloride ($IrCl_4$, AR)	Kunming Boren Precious Metals Co., Ltd.
Ferric nitrate nonahydrate ($Fe(NO_3)_3 \cdot H_2O$, AR)	Xilong Scientific Co., Ltd.
Citric acid ($C_6H_8O_7$, CP)	Chengdu Chemical Reagent Factory
Benzyl alcohol (C_7H_8O, AR)	Damao Chemical Reagent Factory
Methanesulfonic acid (CH_4O_3S, 70%)	Beijing chemicals works
Lead dioxide (PbO_2, AR)	Shanghai Aladdin Biochemical Technology Co., Ltd.
Nafion (C9HF17O5S, 5%)	DuPont