Supporting Information

ZIF-Derived Hollow Carbon Nanoframework Loaded with FeCu Alloy Nanoparticles for Efficient Oxygen Reduction Reaction and Zinc-Air Batteries

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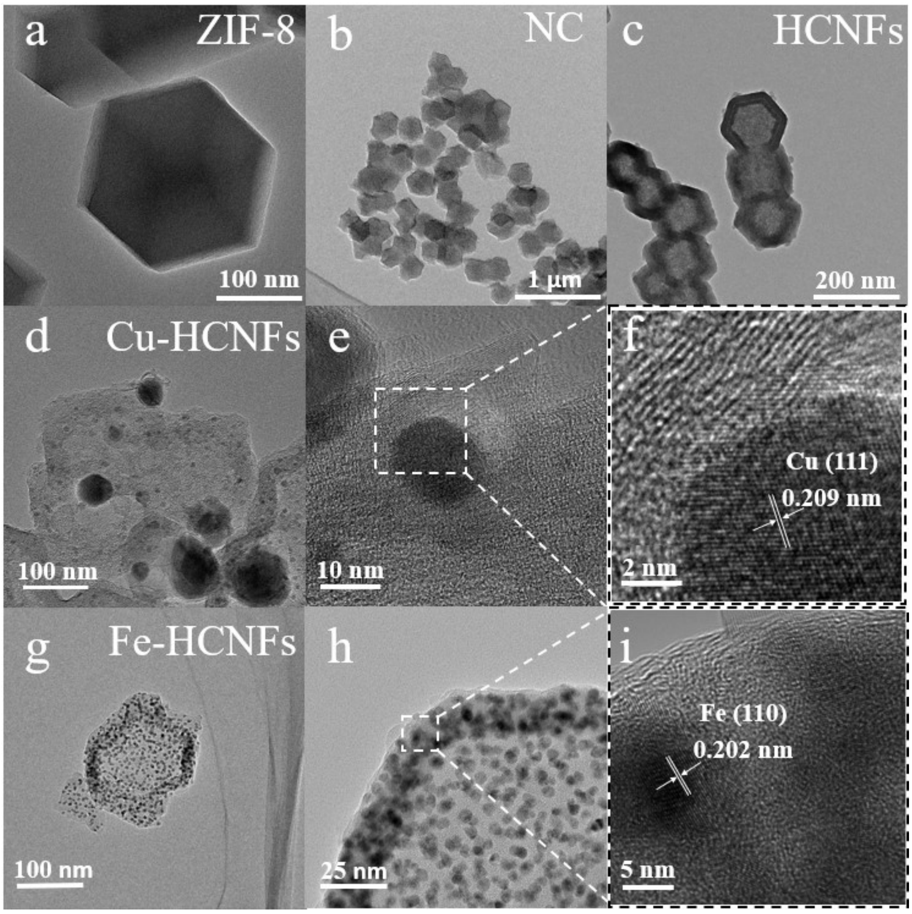

Fig. S1 TEM image of (a) ZIF-8, (b) NC, (c) HCNFs, (d, e) Cu-HCNFs, (g, h) Fe-HCNFs HR-TEM image of (f) Cu particles on Cu-HCNFs, (i) Fe particles on Fe-HCNFs.

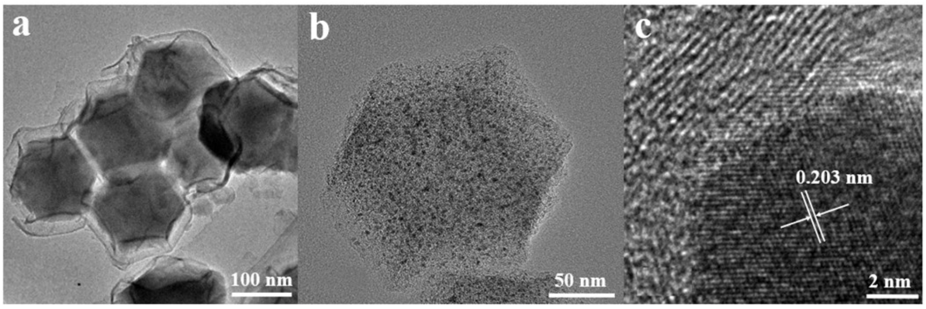

Fig. S2 TEM image of (a) ZIF-8@TA, (b) FeCu-NC, (c) HR-TEM of FeCu alloy particles on FeCu-NC.

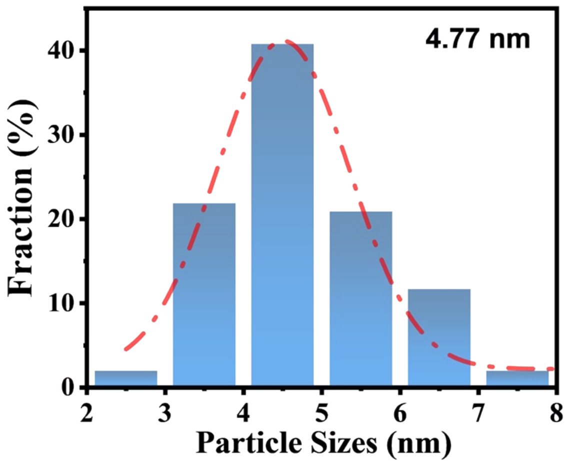

Fig. S3 Particle size distribution plot of FeCu alloy nanoparticles on FeCu-HCNFs.

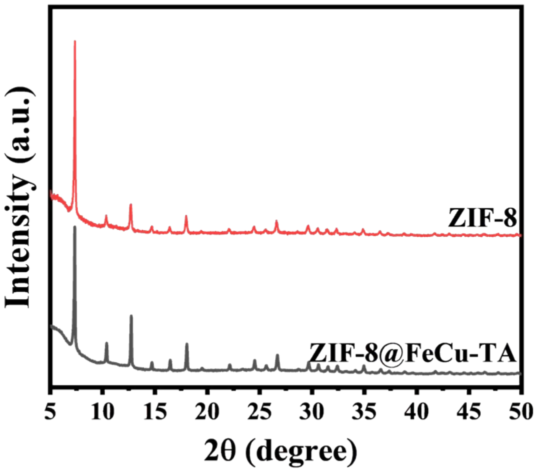

Fig. S4 XRD pattern of ZIF-8 and ZIF-8@FeCu-TA.

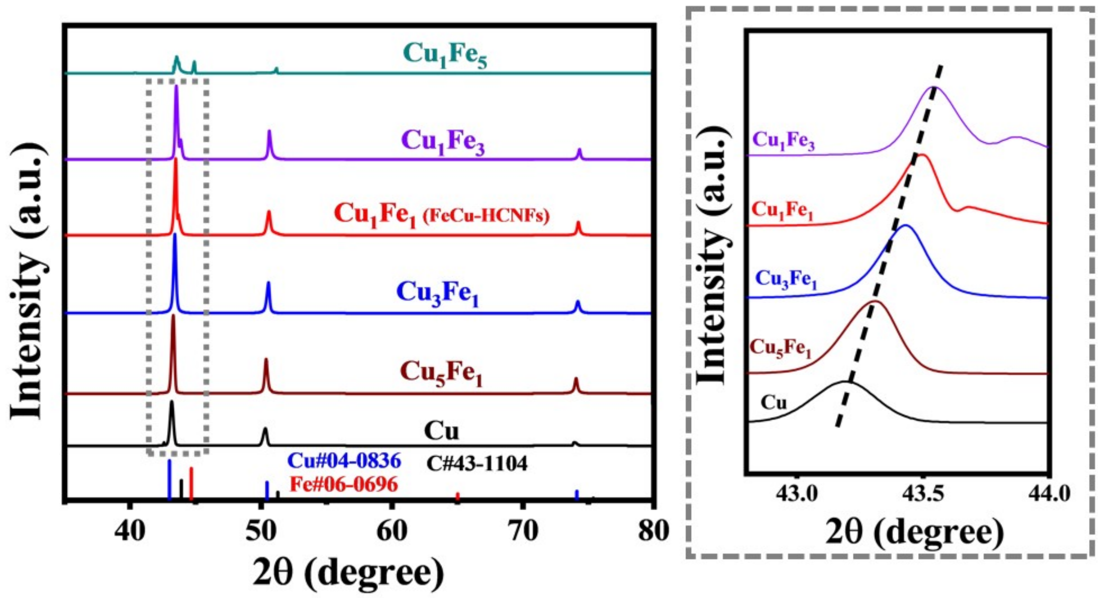

Fig. S5 Rietveld refinement XRD pattern of Cu-HCNFs (black), ,FeCu-HCNFs with a ratio of Cu to Fe = 5:1 (Cu_5Fe_1, brown), 3:1 (Cu_3Fe_1, blue), 1:1 (Cu_1Fe_1, red), 1:3 (Cu_1Fe_3, purple), 1:5 (Cu_1Fe_5, green).

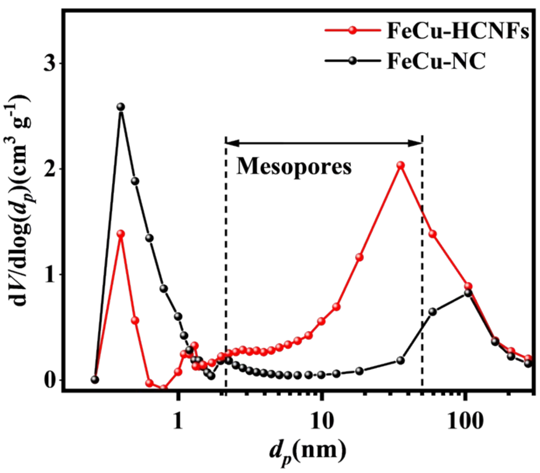

Fig. S6 Pore size distribution plots of FeCu-HCNFs and FeCu-NC.

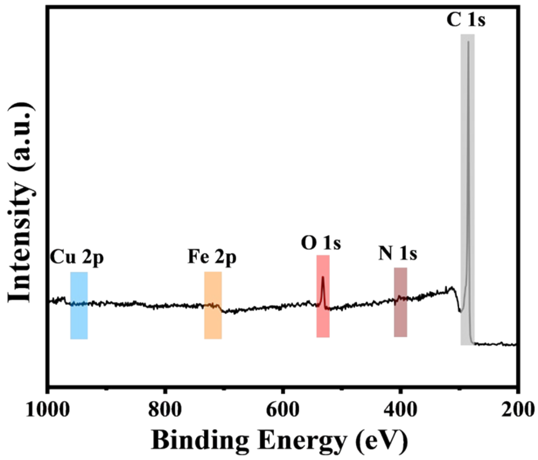

Fig. S7 XPS survey of FeCu-HCNFs.

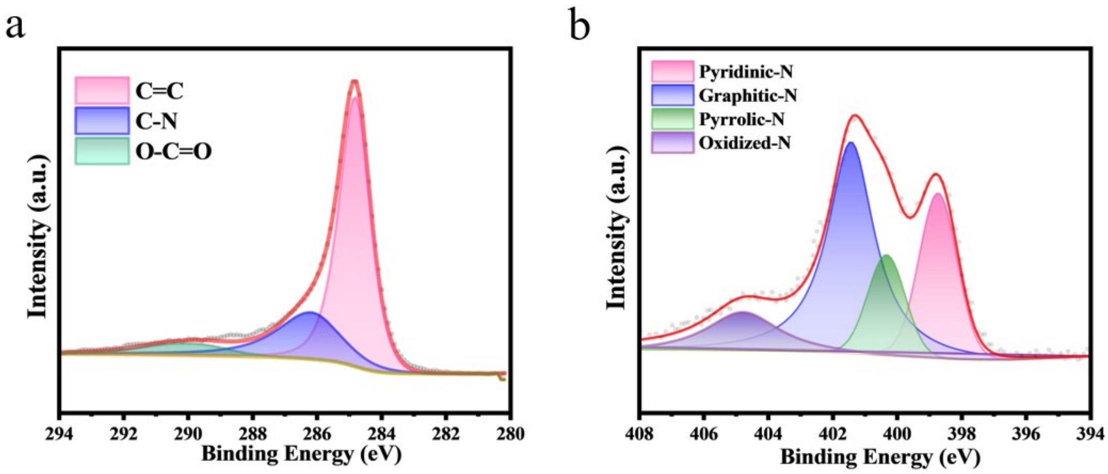

Fig. S8 (a) C 1s and (b) N 1s high-resolution spectrum of FeCu-HCNFs.

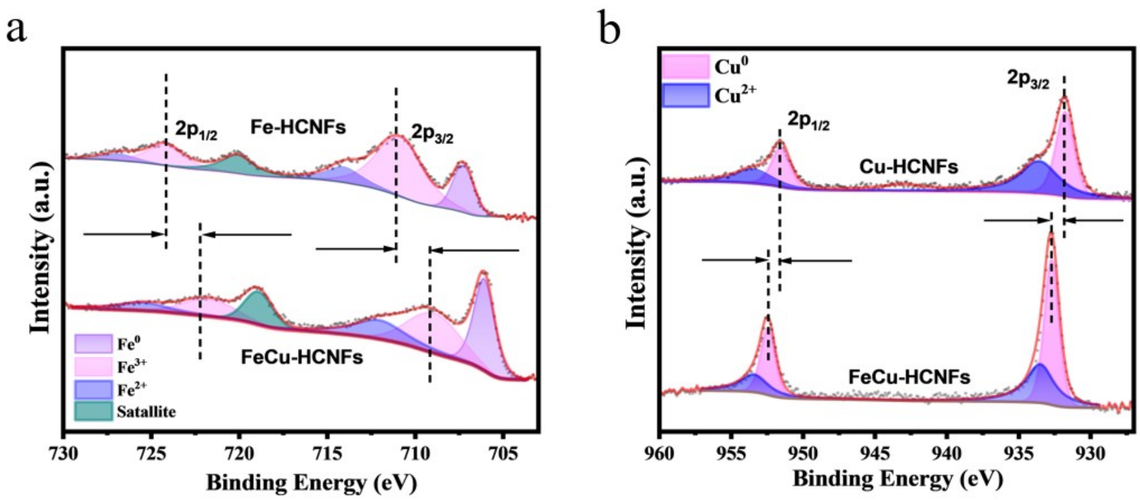

Fig. S9 (a) Cu 2p XPS high-resolution spectrum of Cu-HCNFs and FeCu-HCNFs. and (b) Fe 2p high-resolution spectrum of Fe-HCNFs and FeCu-HCNFs.

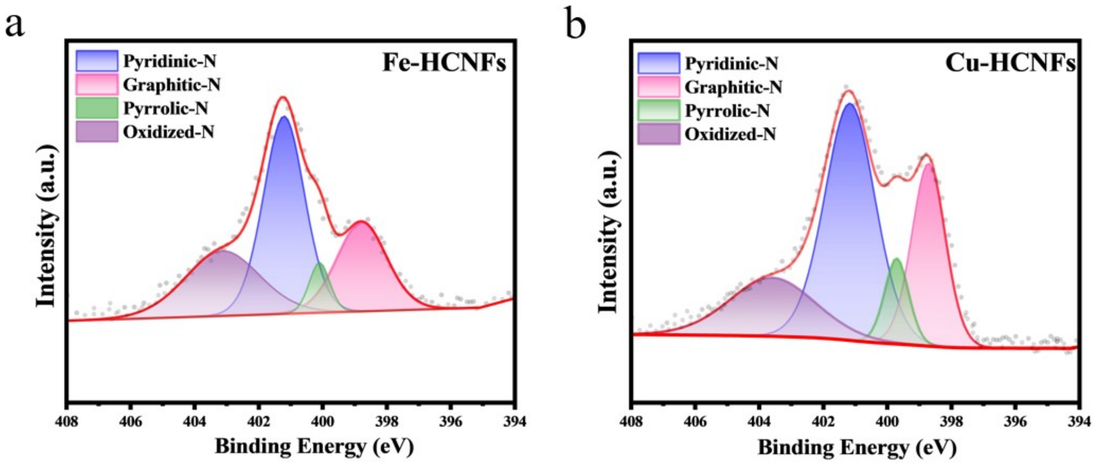

Fig. S10 N 1s high-resolution spectrum of (a) Fe-HCNFs and (b) Cu-HCNFs.

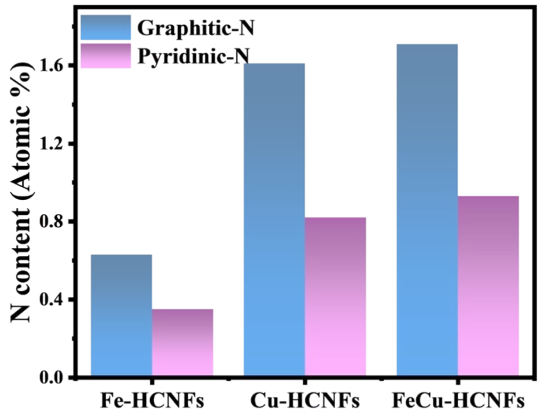

Fig. S11 The comparison of surface graphitic N (red) and pyridinic N (black) content of Fe-HCNFs, Cu-HCNFs and FeCu-HCNFs.

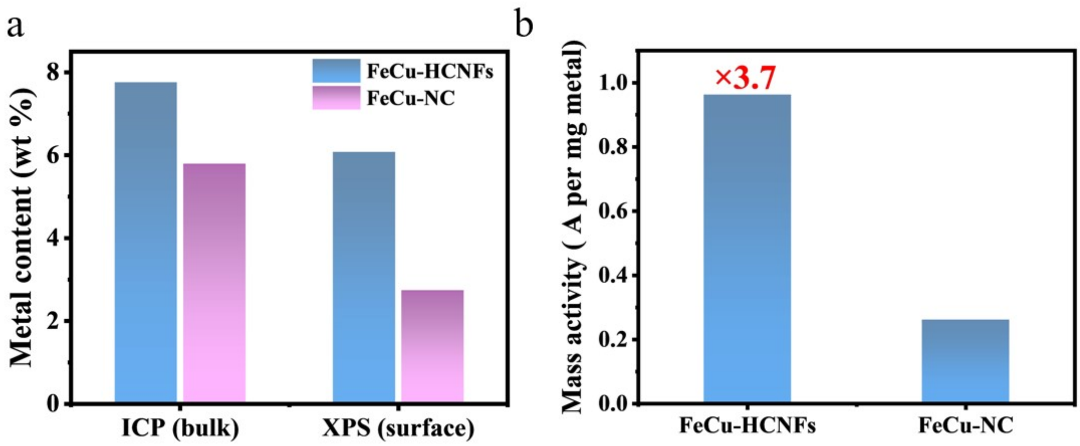

Fig. S12 (a) The comparison of metal content in FeCu-HCNFs (blue) and FeCu-NC (pink) measured by ICP (Bulk content) and XPS (Surface content). (b) The mass activity of FeCu-HCNFs and FeCu-NC.

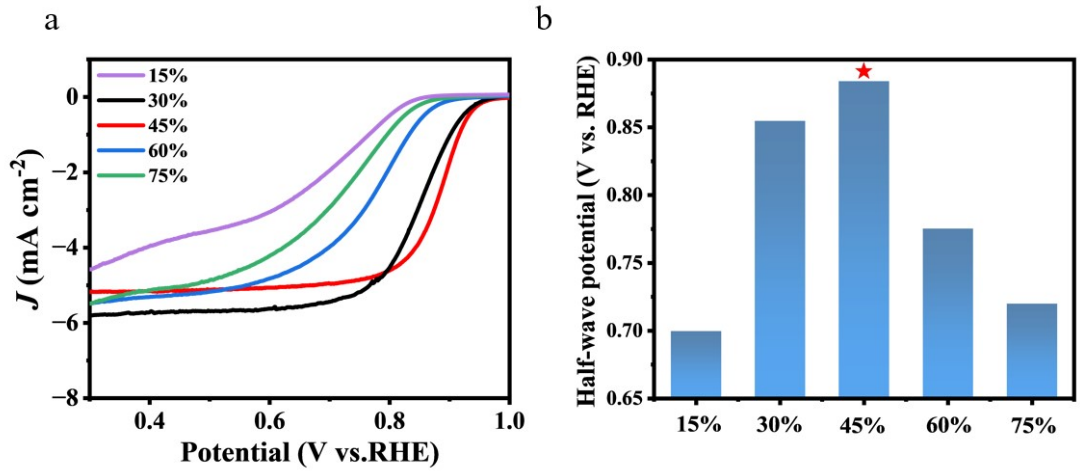

Fig. S13 (a) LSV curves of catalysts with different impregnation ratio and corresponding (b) comparison of half wave potentials.

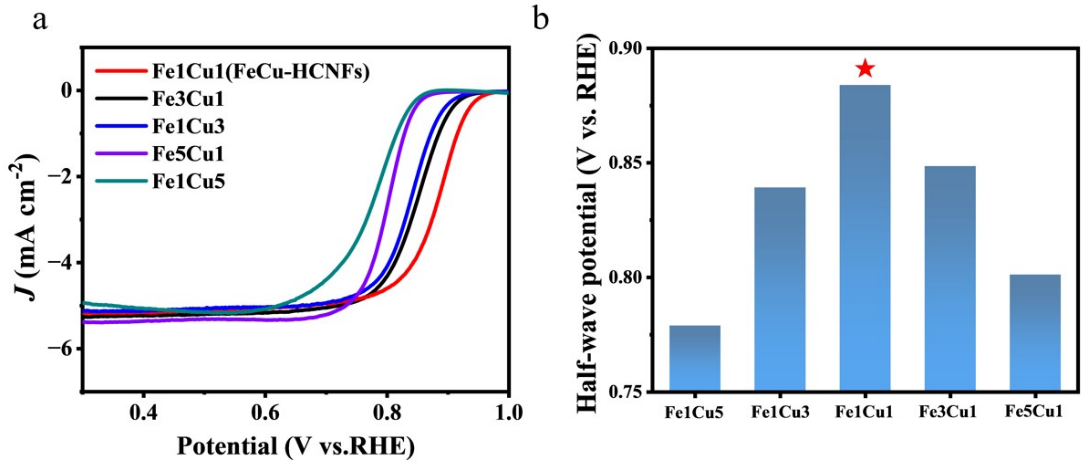

Fig. S14 (a) LSV curves of catalysts with different Fe Cu ratios and corresponding (b) comparison of half wave potentials.

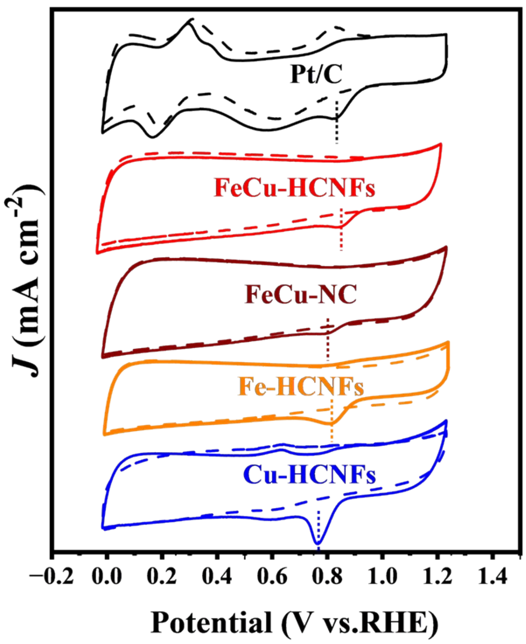

Fig. S15 CV curves of FeCu-HCNFs, TKK-Pt/C, FeCu-NC, Fe-HCNFs, Cu-HCNFs in Ar (dash lines) and O_2 (solid lines) saturated alkaline solutions with a scan rate of 50 mV s^{-1}.

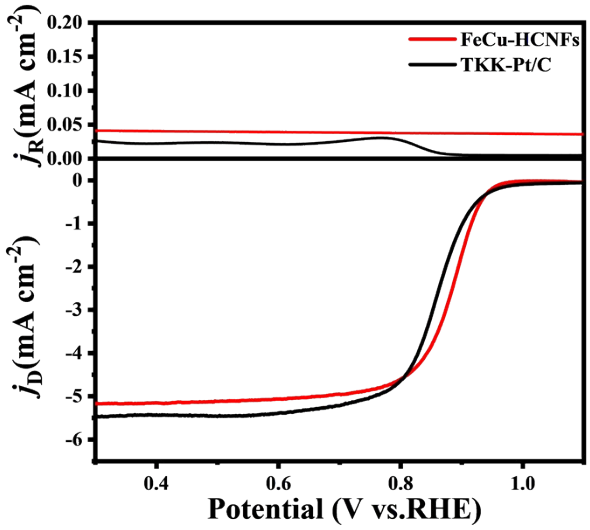

Fig. S16 RRDE voltammograms of FeCu-HCNFs and Pt/C.

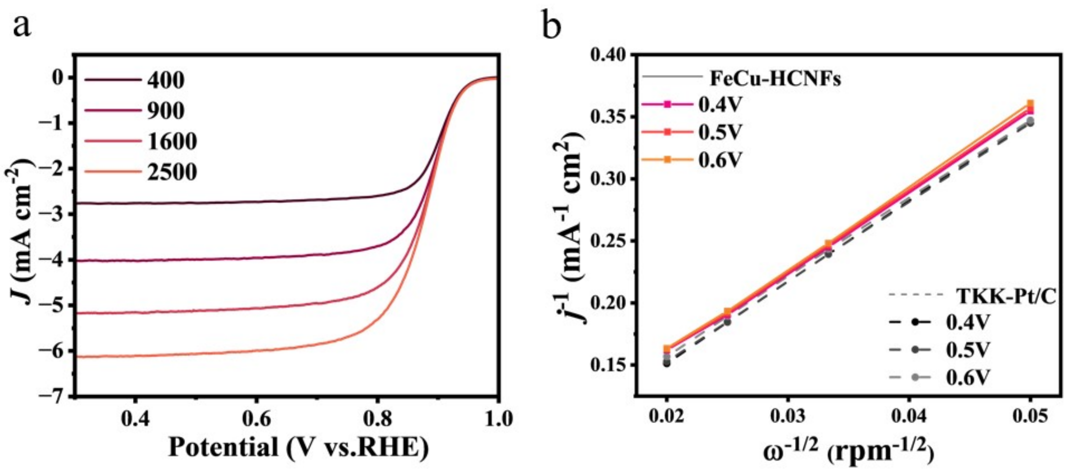

Fig. S17 (a) LSV curves of FeCu-HCNFs at different rotation speeds and (b) corresponding K-L plots of FeCu-HCNFs and Pt/C in 0.1 M KOH.

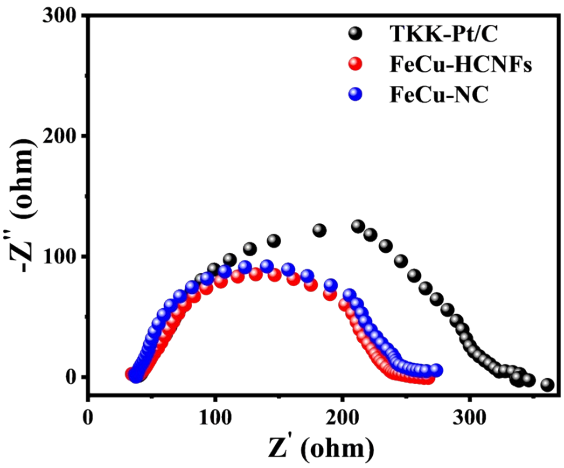

Fig. S18 Impedance data of FeCu-HCNFs, FeCu-NC and Pt/C.

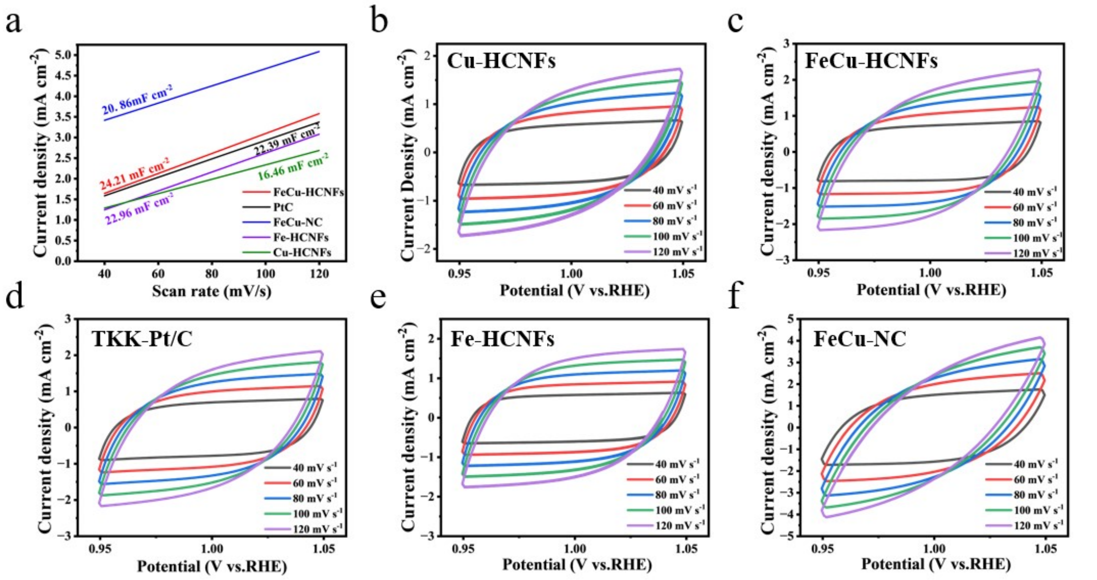

Fig. S19 (a) Calculated C_{dl} by plotting the current density difference against the scan rate. CV curves of (b) Cu-HCNFs, (c) FeCu-HCNFs, (d) Pt/C, (e) Fe-HCNFs and (f) FeCu-NC.

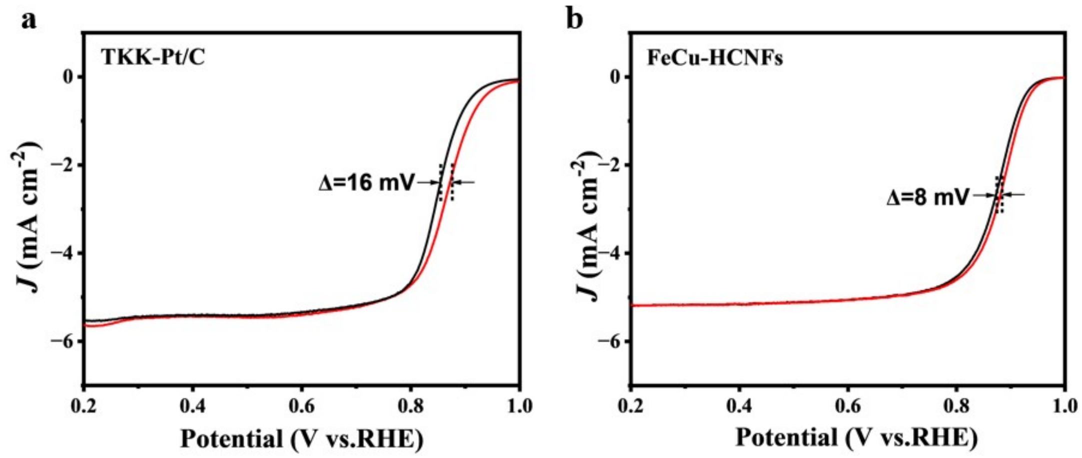

Fig. S20 LSV curves of (a) Pt/C and (b) FeCu-HCNFs before (red) and after (black) ADT (5000 cycles).

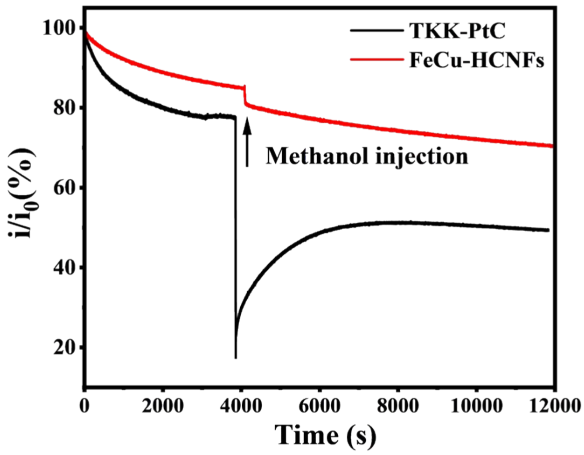

Fig. S21 Methanol tolerance tests of FeCu-HCNFs and Pt/C.

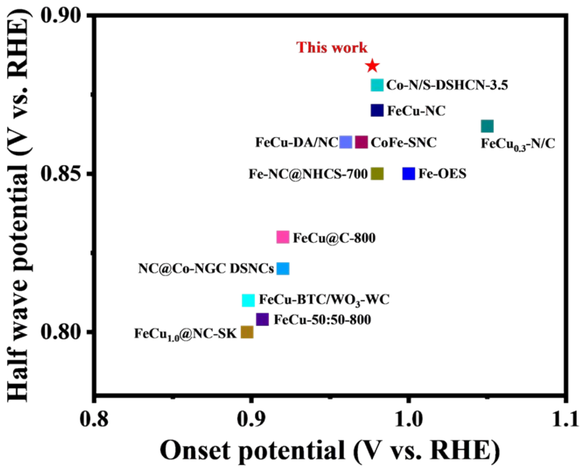

Fig. S22 Comparisons of half-wave potential and onset potential between FeCu-HCNFs and other reported Fe/Cu-based or morphology engineering catalysts in alkaline media.

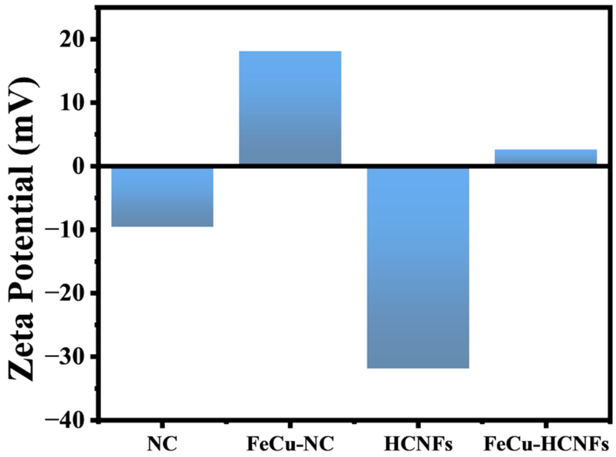

Fig. S23 Comparison of Zeta potentials of NC, FeCu NC, HCNFs, and FeCu HCNFs.

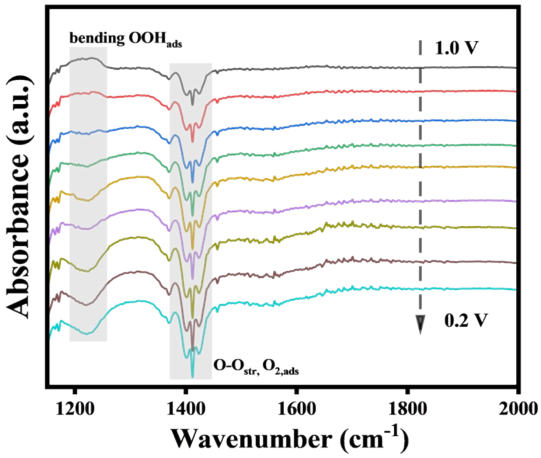

Fig. S24 In-situ infrared data of FeCu HCNFs materials with potential variation.

Table S1. Comparison of element composition and performance of catalysts with different proportions

Samples	Composition (wt %)		Performance
	Fe	Cu	$E_{1/2}$ (V vs. RHE)
Fe_5Cu_1	6.41 %	1.40 %	0.801 V
Fe_3Cu_1	5.86 %	2.11 %	0.849 V
Fe_1Cu_1	3.82 %	3.94 %	0.884 V
Fe_1Cu_3	1.85 %	5.02%	0.840 V
Fe_1Cu_5	1.13 %	5.12%	0.778 V

Table S2. Comparisons of half-wave potential and onset potential between FeCu-HCNFs and other reported Fe/Cu-based or morphology engineering catalysts in alkaline media.

Catalyst	Media	E_{onset} (V vs. RHE)	$E_{1/2}$ (V vs. RHE)
FeCu-HCNFs	0.1 M KOH	0.977	0.884
FeCu-NC [1]	0.1 M KOH	0.98	0.87
FeCu-DA/NC [2]	0.1 M KOH	0.96	0.86
$FeCu_{0.3}$-N/C [3]	0.1 M KOH	1.05	0.865
Co-N/S-DSHCN-3.5 [4]	0.1 M KOH	0.98	0.878
Fe-OES [5]	0.1 M KOH	1.00	0.85
Fe-NC@NHCS-700 [6]	0.1 M KOH	0.98	0.85
CoFe-SNC [7]	0.1 M KOH	0.97	0.86
FeCu@C-800 [8]	0.1 M KOH	0.92	0.83
NC@Co-NGC DSNCs [9]	0.1 M KOH	0.92	0.82
FeCu-BTC/WO_3-WC [10]	0.1 M KOH	0.898	0.81
FeCu-50:50-800 [11]	0.1 M KOH	0.907	0.804
$FeCu_{1.0}$@NC-SK [12]	0.1 M KOH	0.897	0.80

Reference

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