Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

Vanadium Nanobelts Coating Nickel Foam 3D Bifunctional Electrode with Excellent Catalytic Activity and Stability for Water Electrolysis

Yu Yu,[a] Pei Li,[a] Xiaofang Wang,[a] Wenyu Gao,[a] Zongxu Shen,[a] Yanan Zhu,[b] Shuliang Yang,[b] Weiguo Song,[b] and Kejian Ding*[a]*

[a] School of Sciences, Beijing Jiaotong University, Beijing, 100044, P. R. China, E-mail: dkjian@bjtu.edu.cn
[b] Institute of Chemistry, Chinese Academy of Sciences, Beijing, 10009, P. R. China
E-mail: wsong@iccas.ac.cn

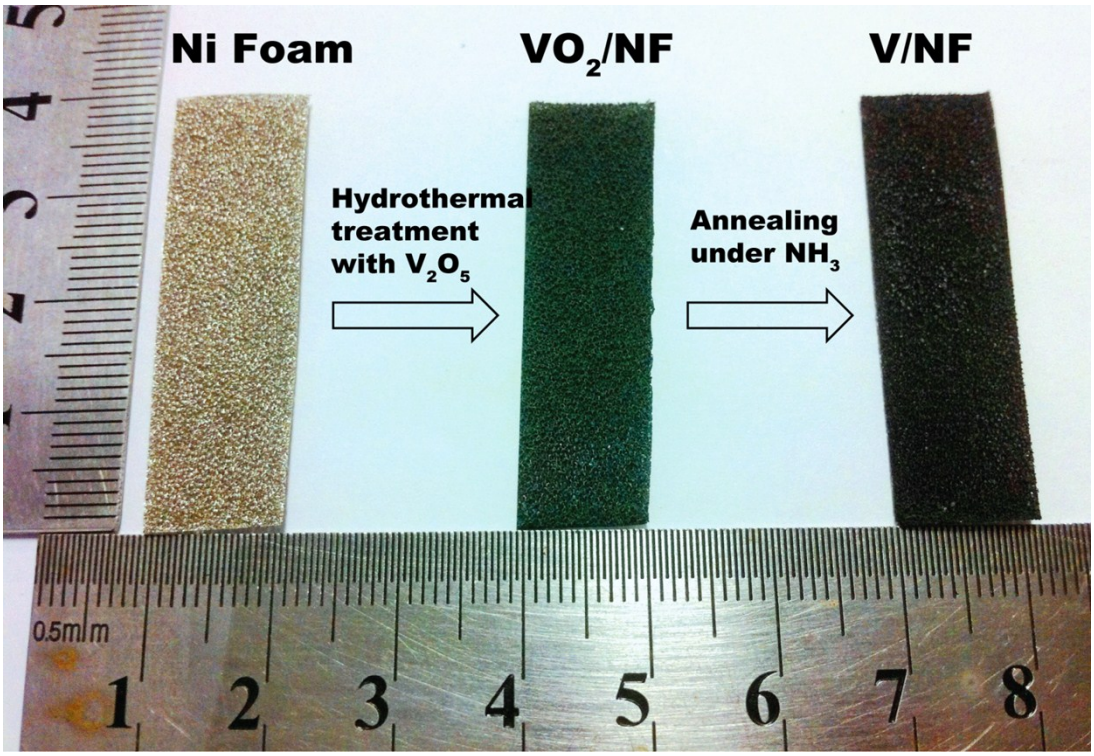

Figure S1. Optical photographs of raw NF, VO_2/NF precursor, and the final V/NF product.

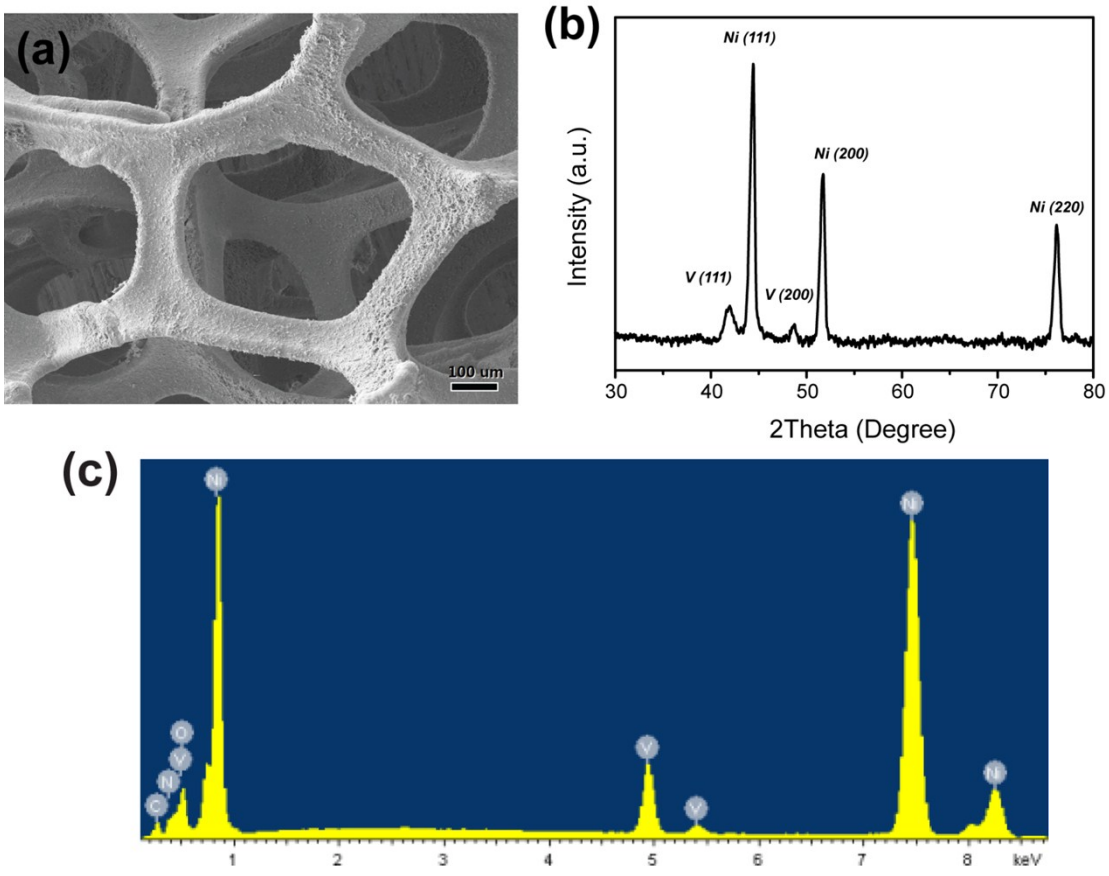

Figure S2. (a) The large-scale SEM image, (b) expanded XRD pattern and (c) EDS spectrum of V/NF.

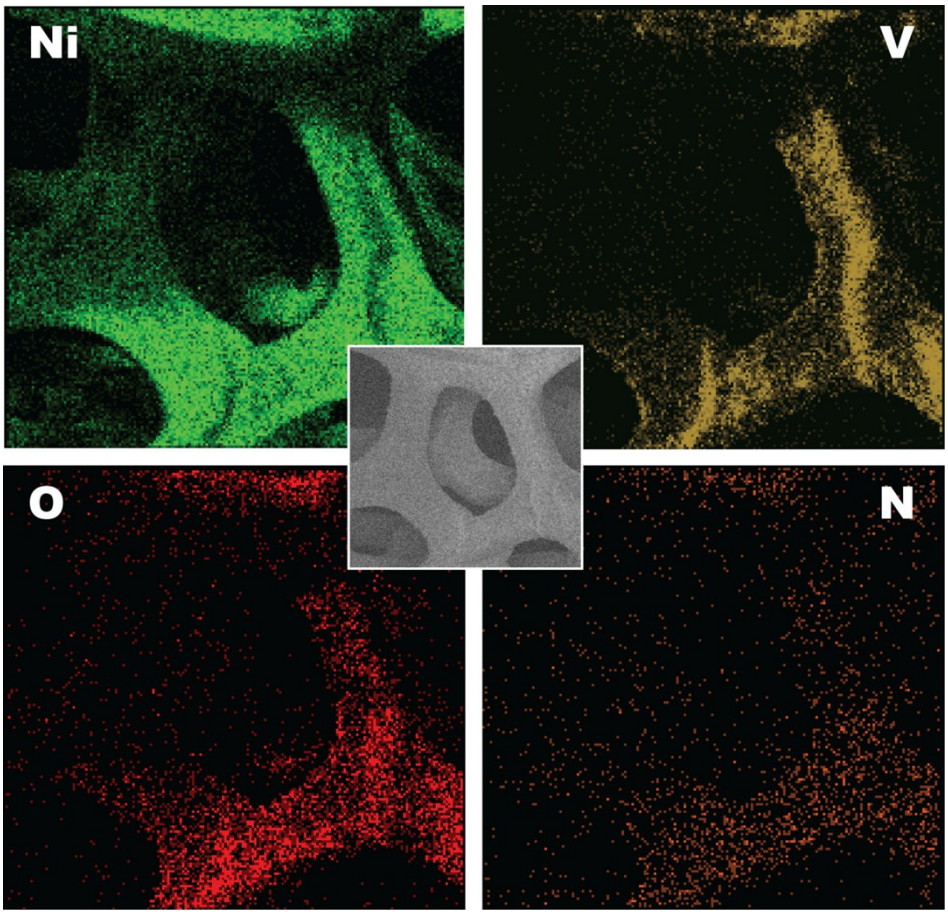

Figure S3. The elements distribution mapping images of V/NF.

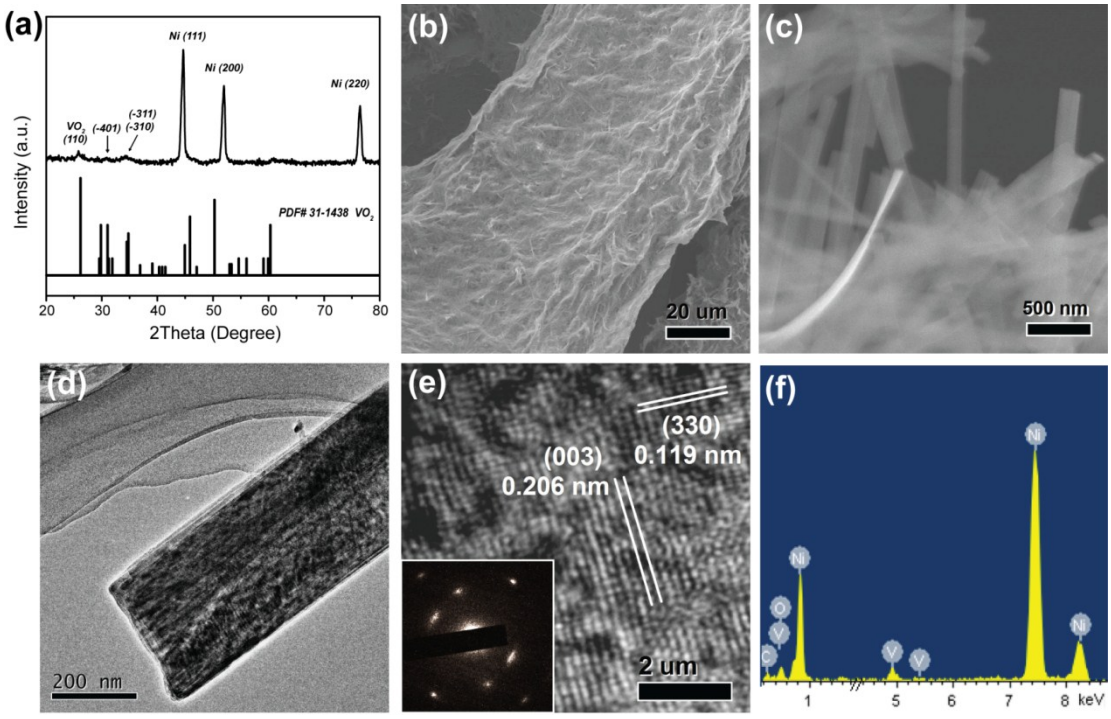

Figure S4. (a) XRD pattern, (b) low- and (c) high-resolution SEM images, and (f) EDS spectrum of VO_2/NF precursor, (d) low- and (e) high-resolution TEM images (SAED pattern shown in the inset) of VO_2 nanobelt.

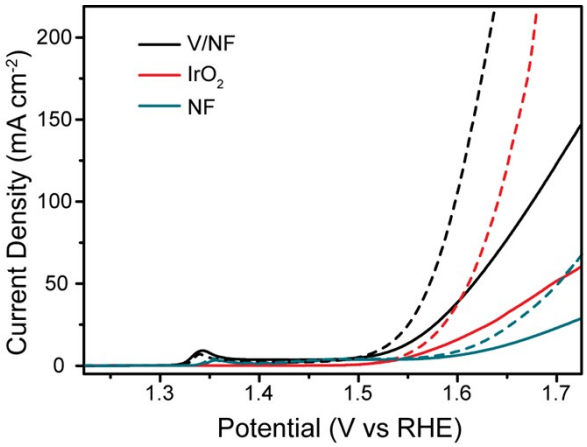

Figure S5. LSV curves for OER of V/NF (black), IrO_2 (red), bare NF (green) at a scan rate of 2 mV s^{-1}. The solid and dash lines present the original and *iR*-corrected curves respectively.

Table S1. The comparation of OER performance among V/NF and the reported highly active electrocatalysts

Materials	***Overpotentials (mV) at 10 mA cm^{-2}***	***Loading density (mg cm^{-2})***	***Electrode substrate***	***Ref***
Co_3O_4/N-rmGO	310	1	Ni foam	[37]
Ni-NiO/N-rGO	240	0.21	Glass carbon (GCE)	[38]
Co_3O_4/Carbon	290	0.2	Cu foil	[39]
$Mn_3O_4/CoSe_2$	450	0.2	GCE	[40]
$LiCoO_2$	~330	0.25	GCE	[41]
$SrNb_{0.1}Co_{0.7}Fe_{0.2}O_{3-\delta}$	420	0.464	GCE	[43]
$La_{0.3}(Ba_{0.5}Sr_{0.5})_{0.7}Co_{0.8}Fe_{0.2}O_{3-\delta}$	~600	0.693	GCE	[44]
$Fe_6Ni_{10}O_x$	286	0.1	GCE	[45]
NiFe layered double hydroxides (LDH)	240	Not given	Ni foam	[46]
NiFe-LDH/CNT	248	0.2	Carbon fiber	[47]
CoMn LDH	293	0.142	GCE	[49]
FeNi-rGO LDH	207	0.25	Ni foam	[50]
N doped NiFe LDH	230	0.7	GCE	[51]
Vanadium nanobelts	292	0.28	Ni foam	This work

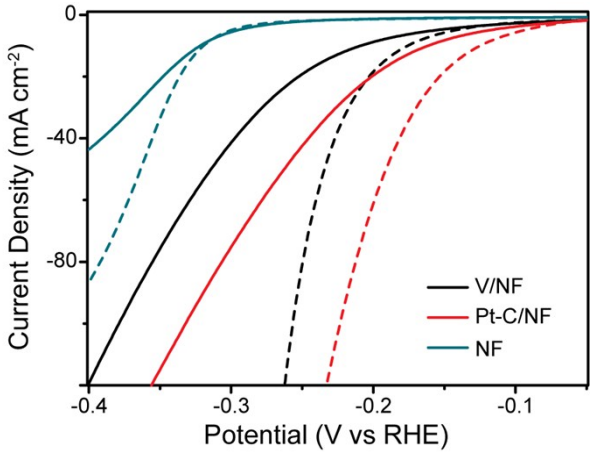

Figure S6. LSV curves for HER of V/NF (black), Pt-C/NF (red), bare NF (green) at a scan rate of 2 mV s^{-1}. The solid and dash lines present the original and *iR*-corrected curves respectively.

Table S2. The comparation of HER performance among V/NF and the reported highly active electrocatalysts

Materials	***Overpotentials (mV) at -10 mA cm^{-2}***	***Loading density (mg cm^{-2})***	***Electrode substrate***	***Ref***
WS_2/rGO	~280	0.4	GCE	[9]
MoS_2/rGO	~180	1	Carbon fiber	[10]
Ni/NiO/$CoSe_2$	~90	0.28	GCE	[11]
$CoSe_2$	139	2.8	Carbon fiber	[12]
Amorphous MoS_xCl_y on vertical graphene	175	-	Graphite disk	[14]
$Fe_{0.43}Co_{0.57}S_2$	~190	0.037	GCE	[15]
NiSe nanofiber	280	0.28	GCE	[16]
Layered MoS_2	149	0.28	GCE	[17]
MoS_2/$CoSe_2$	68	0.28	GCE	[18]
$CoSe_2$ nanobelts	141	4.3	Carbon fiber	[19]
WS_2@P,N,O-graphene	125	0.113	None	[20]

MoS_x@N-graphene	141	0.7	None	[21]
CoP nanoparticle	95 for -20 mA cm^{-2} 85 for -20 mA cm^{-2}	0.9 2	Ti foil	[22]
CoP/CNT	122	0.285	GCE	[23]
CoP nanowire	67	0.92	Carbon fiber	[24]
Ni_2P	130 for -20 mA cm^{-2}	~1	Ti foil	[25]
FeP Nanowire	55	3.2	Ti plate	[26]
MoP	246	0.071	GCE	[27]
Molybdenum Phosphosulfide	117	1	Ti foil	[28]
$Co_{0.6}Mo_{1.4}N_2$	200	0.24	GCE	[29]*
$NiMoN_x$/Carbon	~220 for -5 mA cm^{-2}	0.25	GCE	[30]*
Mo_2C nanowire	~125	0.21	GCE	[31]
MoB	~212 in 1 M H_2SO_4 ~220 in 1 M KOH	2.5 2.3	Carbon paste	[34]
Mo_2C	~210 in 1 M H_2SO_4 ~190 in 1 M KOH	1.4 0.8	Carbon paste	[34]
g-C_3N_4@nitrogen-doped graphene	240	0.1	GCE	[33]
N,G-graphene	420	0.2	GCE	[36]
porous C_3N_4@nitrogen-doped graphene	80	Not given	None	[36]
Vanadium nanobelts	176	0.28	Ni foam	This work*

*The electrolyte was 0.1 M $HClO_4$ in ref [23], [24], 1 M KOH in this work, and 0.5 M H_2SO_4 in other unmarked cases.

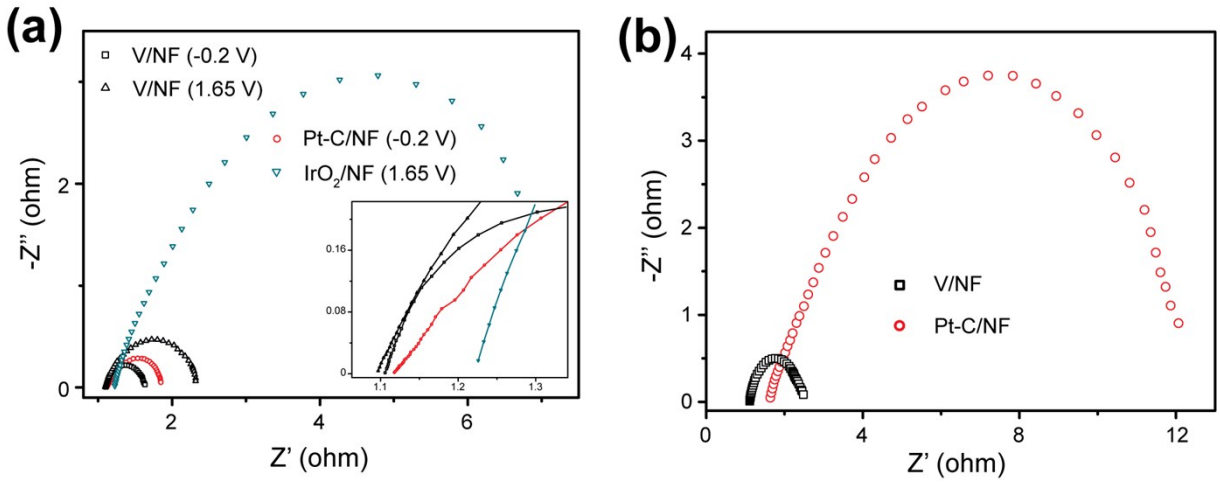

Figure S7. (a) Electrochemical impedance spectra (EIS) of V/NF (at -0.2 and 1.65 V vs RHE), Pt-C/NF (at -0.2 V vs RHE), and IrO_2/NF (at 1.65 V vs RHE) in the three electrode system, the inset shows the amplification of high frequency region; (b) EIS of V/NF and Pt-C/NF in two electrode system with the same materials as both electrodes.

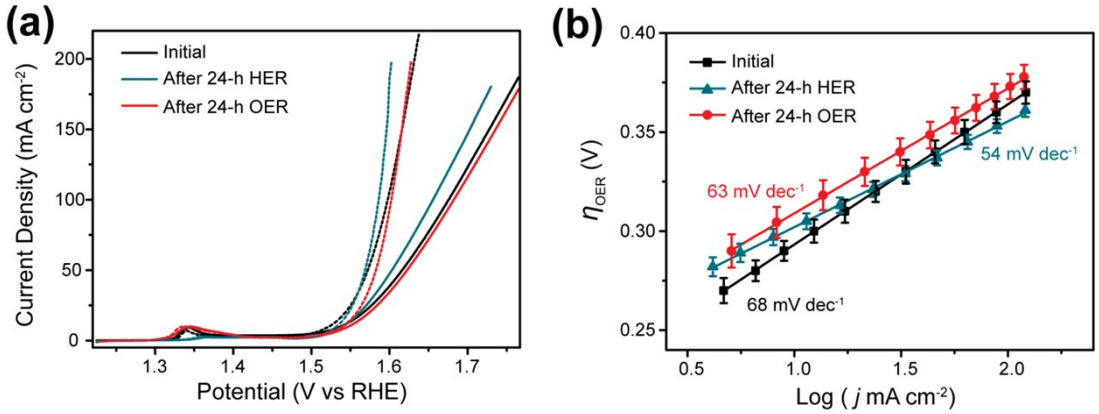

Figure S8. (a) LSV curves for OER of fresh V/NF (black), V/NF after 24-h HER (green), V/NF after 24-h OER (red) at a scan rate of 2 mV s^{-1}. The solid and dash lines present the original and *iR*-corrected polarization curves respectively. (b) The corresponding Tafel plots of the three samples.

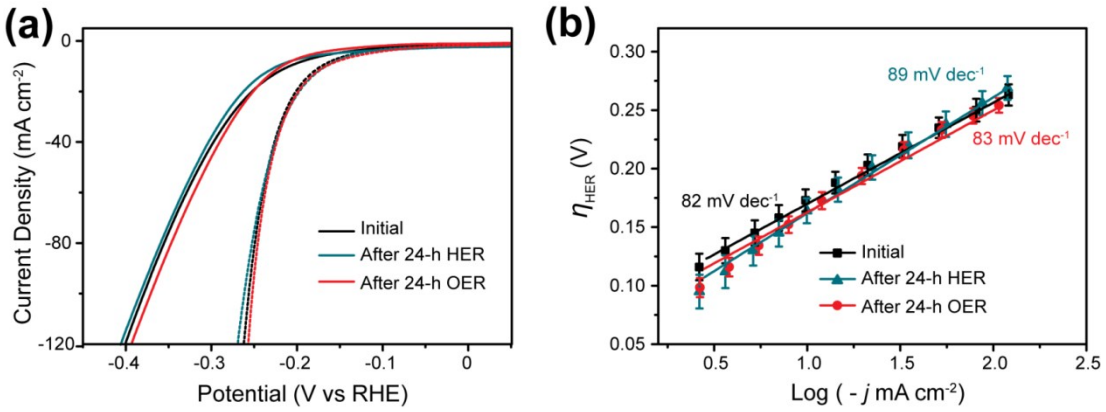

Figure S9. (a) LSV curves for HER of fresh V/NF (black), V/NF after 24-h HER (green), V/NF after 24-h OER (red) at a scan rate of 2 mV s^{-1}. The solid and dash lines present the original and *iR*-corrected polarization curves respectively. (b) The corresponding Tafel plots of the three samples.

Table S3. The comparation of water electrolysis performance among V/NF and the reported highly active electrocatalysts

Materials	***Applied potentials (V)***		***Loading density***	***Electrode***	***Ref***
	at 10 mA cm^{-2}	***at 20 mA cm^{-2}***	***(mg cm^{-2})***	***substrate***	
NiFe layered double hydroxide	1.70	~1.74	unknown	Ni foam	[12a]
NiSe nanowire	1.63	~1.72	2.8	Ni foam	[17]
$NiCo_2S_4$ nanowire	1.68	~1.83	4	Carbon cloth	[18]
Co-P films	1.65	~1.67	2.71	Cu foil	[20]
Vanadium nanobelts	1.74	1.80	0.28	Ni foam	This work

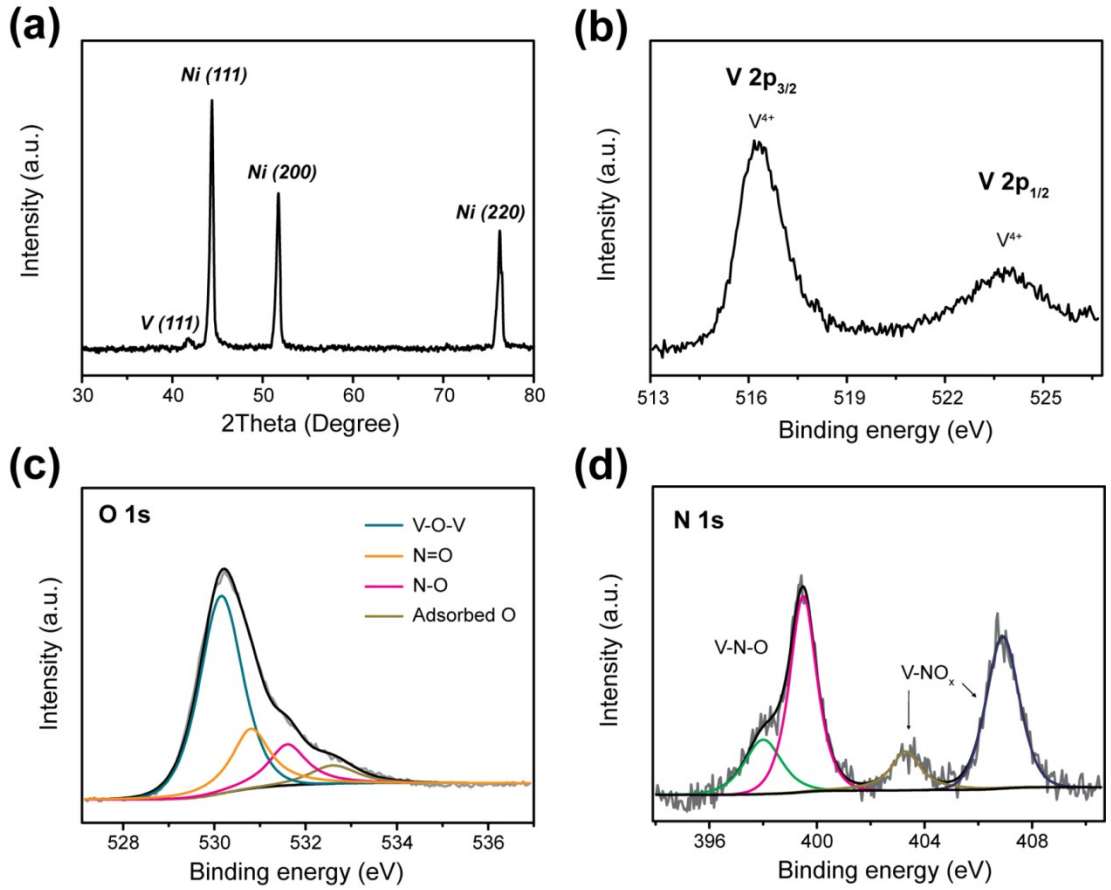

Figure S10. (a) XRD pattern of V/NF, (b) V 2p, (c) O 1s, and (d) N 1s XPS spectra of vanadium nanobelts in V/NF after 24-h OER.

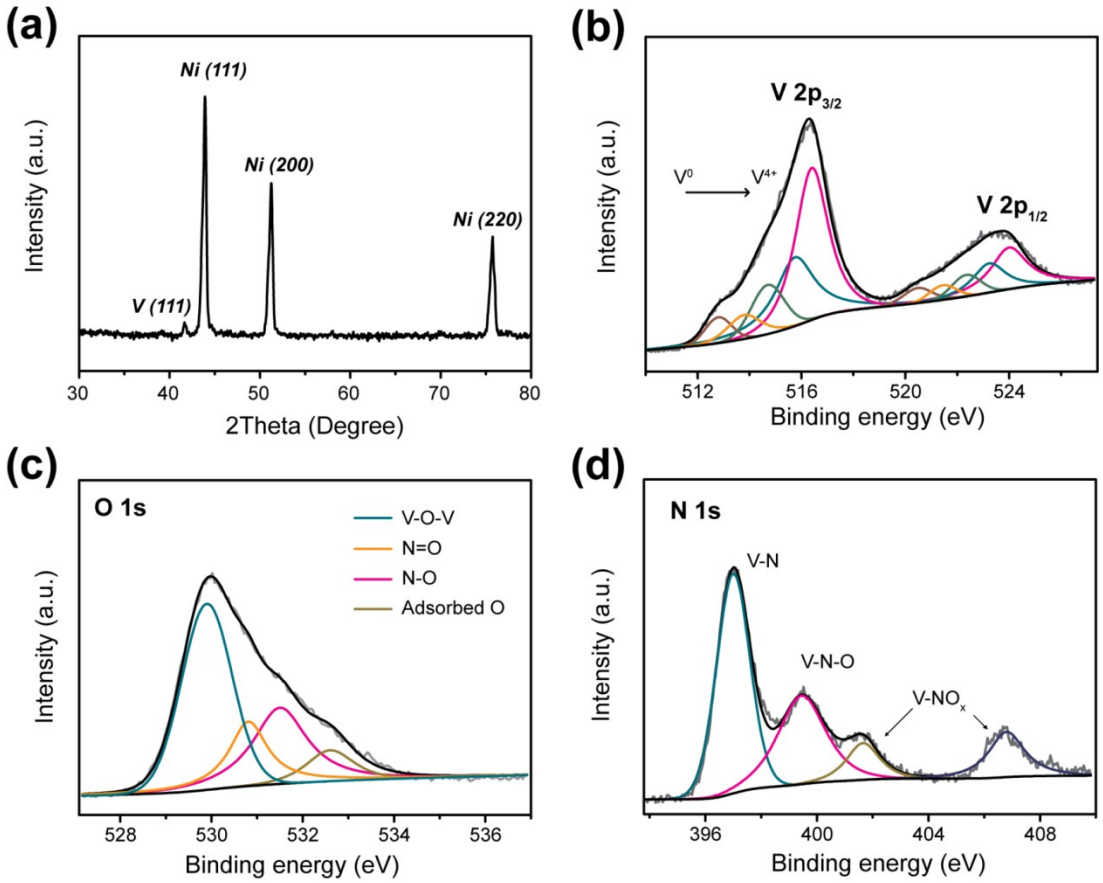

Figure S11. (a) XRD pattern of V/NF, (b) V 2p, (c) O 1s, and (d) N 1s XPS spectra of vanadium nanobelts in V/NF after 24-h HER.

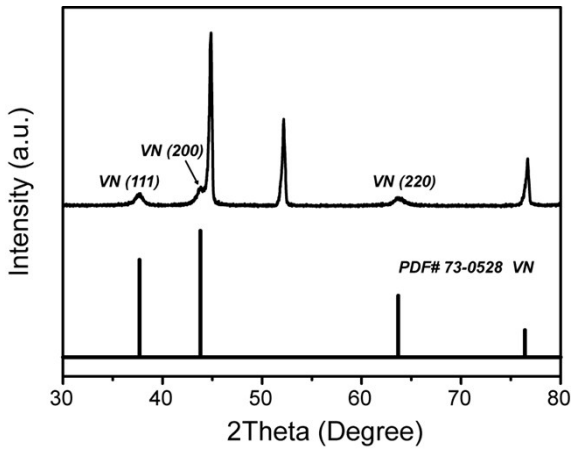

Figure S12. (a) XRD pattern of VN/NF.

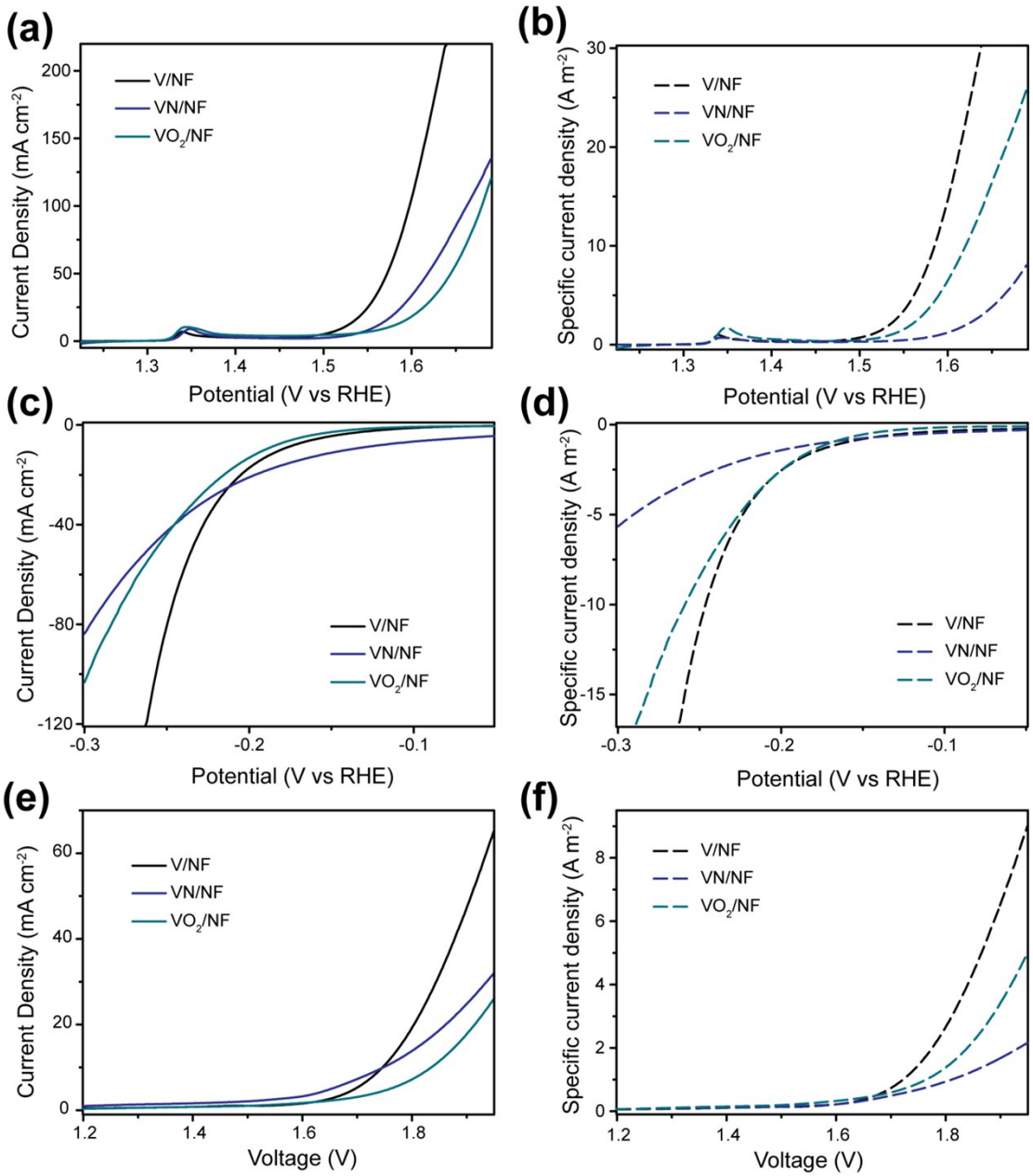

Figure S13. (a) *iR*-corrected OER polarization curves, (b) OER polarization curves, (c) LSV curves without *iR*-correction of water electrolysis form V/NF, VO_2/NF, and VN/NF electrodes.