Supporting Information

MoS_2-Ni_3S_2 Heteronanorods as Efficient and Stable Bifunctional Electrocatalysts for Overall Water Splitting

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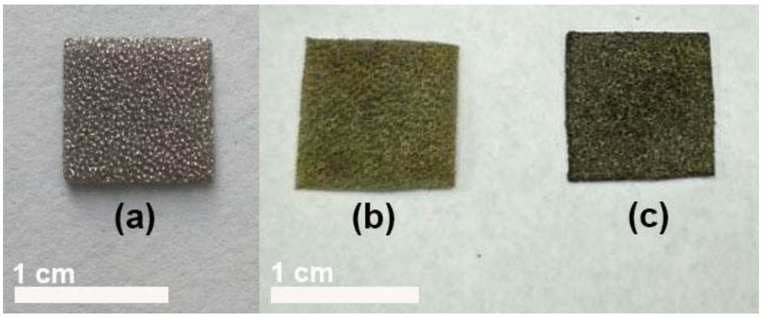

Figure S1. Photographs of (a) NF, (b) Ni_3S_2/NF, and (c) MoS_2-Ni_3S_2 HNRs/NF.

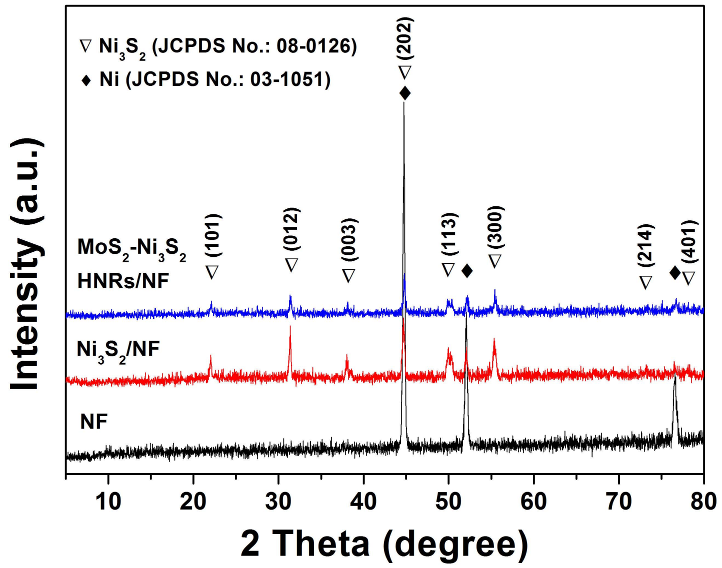

Figure S2. XRD patterns of NF, Ni_3S_2/NF and MoS_2-Ni_3S_2 HNRs/NF.

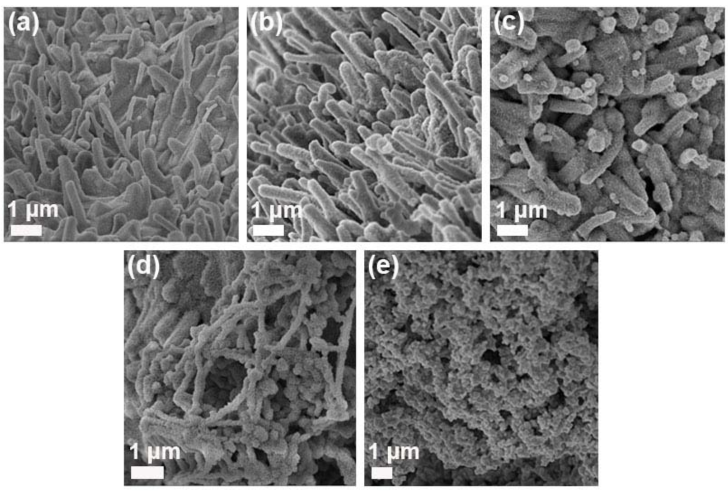

Figure S3. SEM images of various MoS_2-Ni_3S_2 obtained with varied AHM/NF mass ratios of (a) 0.02, (b) 0.07, (c) 0.12, (d) 0.19, and (e) 0.28.

Table S1. Comparison of the HER performance of MoS_2/Ni_3S_2 HNRs/NF with other reported non-precious HER electrocatalysts in basic electrolyte.

Catalysts	η_{10} (mV)	η_{onset} (mV)	Tafe Slopel (mV dec^{-1})	Electrolyte	Ref.
MoS_2-Ni_3S_2 HNRs/NF	98	31	61	1.0 M KOH	*This work*
Ni_3S_2 nanosheet arrays/Ni foam	223	--	--	1.0 M KOH	1
Ni_3S_2 particles	335	--	97	1.0 M KOH	*2*
Ni_3S_2 nanoparticles/CNTs	480	350	102	1.0 M KOH	3
NiSe nanowires/Ni foam	96	--	120	1.0 M KOH	4
NiCo-P hollow nanocubes	150	--	61	1.0 M KOH	5
Ni-Fe/nanocarbon	219	--	110	1.0 M KOH	6
Ni_1Mn_1 porous materials	360	150	--	1.0 M KOH	7
$NiSe_2$ nanosheets	184	90	184	1.0 M KOH	8
Ni_2P nanoparticles	230	150	100	1.0 M KOH	*9*
$NiCo_2S_4$ nanowires/ carbon cloth	--	230	141	1.0 M KOH	10
NiSn@C	--	100	145	1.0 M NaOH	11
MoS_2/graphene/Ni foam	> 600	25	98	1.0 M KOH	12
MoS_{2+x} nanoparticles	310	200	84	1.0 M KOH	13
Co-Mo/Ti	75	--	--	1.0 M KOH	14
MoB nanoparticles	230	150	59	1.0 M KOH	15
Mo_2C nanoparticles	190	150	60	1.0 M KOH	15
Carbon paper/carbon tubes/Co-S	190	50	131	1.0 M KOH	16
Co/N-doped carbon	260	~45	91.2	1.0 M KOH	17
N, P, Co-doped graphene	> 600	> 350	145	1.0 M KOH	18
CoP nanowires/ carbon cloth	110	38	129	1.0 M KOH	19
WC nanoparticles/ CNT	137	16	106	1.0 M KOH	20
WN nanowires/ carbon cloth	285	100	170	1.0 M KOH	21

Table S2. BET surface of NF, Ni_3S_2/NF and MoS_2-Ni_3S_2/NF determined by N_2 isothermal sorption.

Catalysts	BET surface area (m^2 g^{-1})
NF	14.8
N_3S_2/NF	10.1
MoS_2-Ni_3S_2/NF (0.02)	3.9
MoS_2-Ni_3S_2/NF (0.07)	4.1
MoS_2-Ni_3S_2/NF (0.12)	4.0
MoS_2-Ni_3S_2/NF (0.19)	3.8
MoS_2-Ni_3S_2/NF (0.29)	4.0

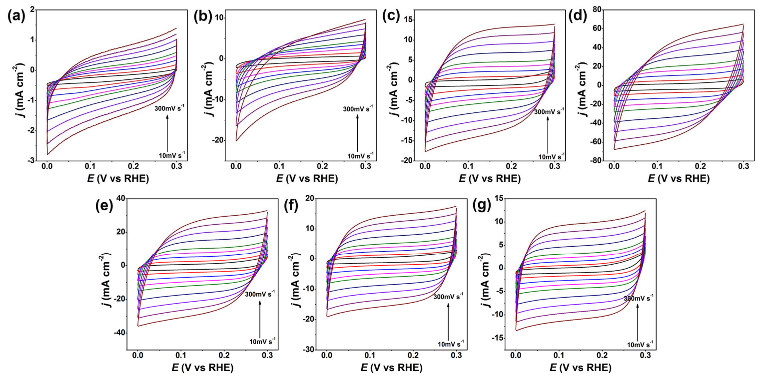

Figure S4. Cyclic voltammograms of (a) Ni foam, (b) Ni_3S_2/NF, and of various MoS_2-Ni_3S_2 obtained with different AHM/NF mass ratios of (c) 0.02, (d) 0.07, (e) 0.12, (f) 0.19, and (g) 0.28.

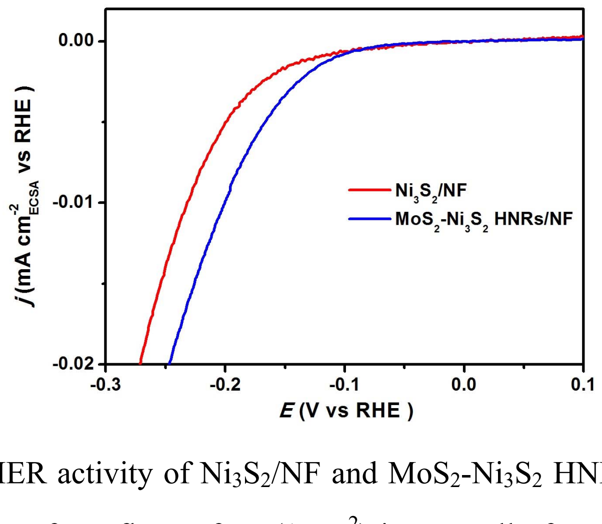

Figure S5. Specific HER activity of Ni_3S_2/NF and MoS_2-Ni_3S_2 HNRs/NF in 1.0 M KOH. The specific capacitance for a flat surface (1 cm^2) is generally found to be in the range of 20-60 μF cm^{-2}, and it is assumed as 40 μF cm^{-2} in the following calculations of ECSA. The ECSA is determined via dividing C_{dl} by 40 μF cm^{-2}, and the specific HER activity is calculated via normalizing the current by the corresponding ECSA.

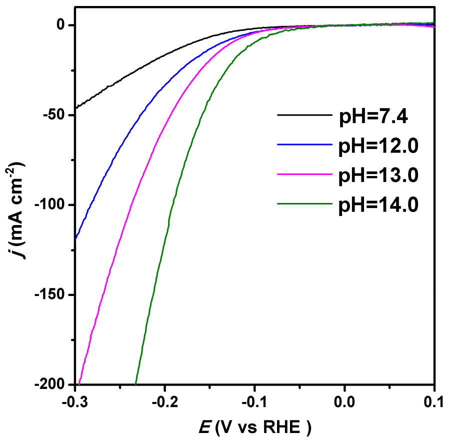

Figure S6. HER performance on MoS_2-Ni_3S_2 HNRs/NF at different pH level.

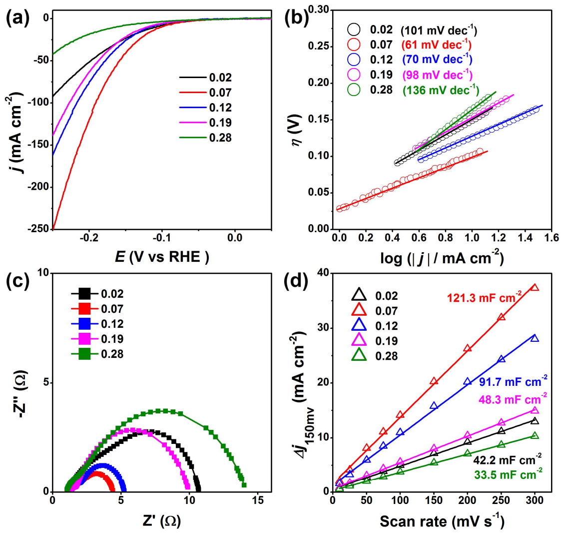

Figure S7. (a) Polarization curves and (b) the corresponding Tafel plots of a series of MoS_2-Ni_3S_2/NF in 1M KOH solution, which are synthesized with varied feeding AHM/NF ratios (0.02 ~ 0.28). (c) Nyquist plots (at η = 200 mV), and (d) Estimation of C_{dl} by plotting the current density variation ($\Delta j = (j_a - j_c)/2$, at 150 mV vs. RHE; data obtained from the CV in Figure S4) against scan rate to fit a linear regression.

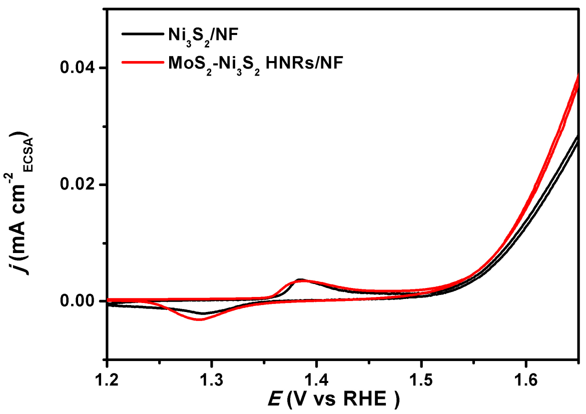

Figure S8. Specific OER activity of Ni_3S_2/NF and MoS_2-Ni_3S_2 HNRs/NF in 1.0 M KOH. The specific capacitance for a flat surface (1 cm^2) is generally found to be in the range of 20-60 μF cm^{-2}, and it is assumed as 40 μF cm^{-2} in the following calculations of ECSA. The ECSA is determined via dividing C_{dl} by 40 μF cm^{-2}, and the specific OER activity is calculated via normalizing the current by the corresponding ECSA.

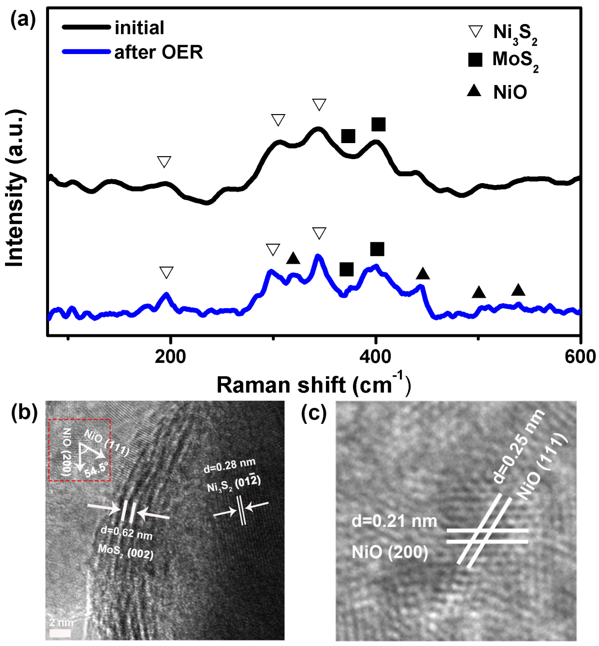

Figure S9. (a) Raman spectra of MoS_2/Ni_3S_2 HNRs/NF before and after OER test, (b) HR-TEM images of MoS_2/Ni_3S_2 HNRs/NF after OER test, and (c) HR-TEM image of the area highlighted by red box in (b). The Raman spectra clearly identifies the present of NiO species in the MoS_2/Ni_3S_2 HNRs/NF, which is also observed by TEM investigation.

Table S3. Comparison of the OER performance of MoS_2/Ni_3S_2 HNRs/NF with other reported OER electrocatalysts in basic electrolyte.

Catalysts	η_{10} (mV)	η_{onset} (mV)	Tafel Slope (mV dec^{-1})	Electrolyte	Ref.
MoS_2-Ni_3S_2 HNRs/NF	249	195	66	1.0 M KOH	*This work*
Ni_3S_2/Ni foam	260	-	-	1.0 M KOH	[1]
carbon sheets @Ni−Mn	270	250	40	1.0 M KOH	[22]
(Ni, Co)$_{0.85}$Se@NiCo-LDH	216	-	77	1.0 M KOH	[23]
NiO_x/NiOOH	320	240	58	1.0 M NaOH	[24]
CoNi-LDH/Fe-porphyrin-layer-by-layer	264	230	37.6	1.0 M KOH	[25]
nickel–iron oxide/C	310	-	42	1.0 M KOH	[26]
FeOOH/CeO_2HLNTs-NF	~230	210	92.3	1.0 M NaOH	[27]
$Ni_{0.75}V_{0.25}$-LDH	350	250	50	1.0 M KOH	[28]
$Ni_xCo_{2x}(OH)_{6x}$@Ni	305	263	78	1.0 M KOH	[29]
$Ni_{45}Fe_{55}$ oxyhydroxide	310	-	35	0.1 M KOH	[30]
FeNi-rGO LDH	206	195	39	1.0 M KOH	[31]
NiFe LDHs	305	-	40	1.0 M KOH	[32]
Ni_xCo_3-xO_4	~620	-	66	1.0 M NaOH	[33]
MoO_2–CoO–Carbon	270	240	36.7	1.0 M KOH	[34]
Au@Co_3O_4	390	-	60	0.1 M KOH	[35]
3D- Co/ cobaltphytate nanoplates	265	-	69	1.0 M KOH	[36]
CoCr LDH nanosheets	340	240	81	1.0 M NaOH	[37]
FeOOH/Co/FeOOH	~245	-	32	1.0M NaOH	[38]
Co_5Mn-LDH/MWCNT	300	-	73.6	1.0 M KOH	[39]
RuO_2	350	~250	85	1.0 M KOH	[40]

Table S4. Comparison of overall water splitting performance of MoS_2/Ni_3S_2 HNRs/NF with recently reported bi-functional electrocatalysts in basic electrolyte.

Catalysts	**HER η_{10} (mV)**	**OER η_{10} (mV)**	**Overall water splitting cell voltage (V, @10 mA cm^{-2})**	**Electrolyte**	**Ref.**
MoS_2-Ni_3S_2 HNRs/NF	98	249	1.50	1.0 M KOH	*This work*
MoS_2/Ni_3S_2 particles	110	218	1.56	1.0 M KOH	41
NiS/Ni foam	158 mV 20 mA cm^{-2}	335 mV 50 mA cm^{-2}	1.64	1.0 M KOH	42
NiFe nanosheets/$NiCo_2O_4$ nanoflakes/NF	105	250	1.67	1.0 M KOH	43
Ni_2P/Ni/NF	98	200	1.49	1.0 M KOH	44
Ni@NC	190	390	-	0.1 M KOH	45
Ni_3FeN nanoparticles	158	280	-	1.0 M KOH	46
Ni_3Se_2 nanoforest/Ni foam	203	353 mV 100 mA cm^{-2}	1.612	1.0M KOH	47
EG/$Co_{0.85}$Se/NiFe-LDH	260	270 mV 150 mA cm^{-2}	1.67	1.0M KOH	48
β-$Ni(OH)_2$-OER and $NiSe_2$	184	415	~1.78	1.0M KOH	8
carbon fiber paper (CP) @Ni-P	117	180 mV 20 mA cm^{-2}	1.63	1.0 M KOH.	49
Bi_2Te_3@CoNiMo on Ni foam	-	80	1.41	0.9 M KOH	50
$Ni_{2.5}Co_{0.5}$Fe/NF	~150	275	1.62	1.0 M KOH	51
Ni/NiP	130	270 mV 30 mA cm^{-2}	1.61	1.0 M KOH	52
NiMn-rGO	~428	260	-	1.0 M KOH	53
$Ni_xCo_{3-x}O_4$/NiCo/$NiCoO_x$	155	337	1.75	1.0 M KOH	54
Ni_xP_y-325	160 mV 20 mA cm^{-2}	320	1.57	1.0 M KOH	51
NiFeP/Ni_2P	183	277	-	1.0 M KOH	55
Ni–P foam	135	1.45	1.64	1.0 M KOH	56
V/NF	176	292	1.74	1.0 M KOH	57

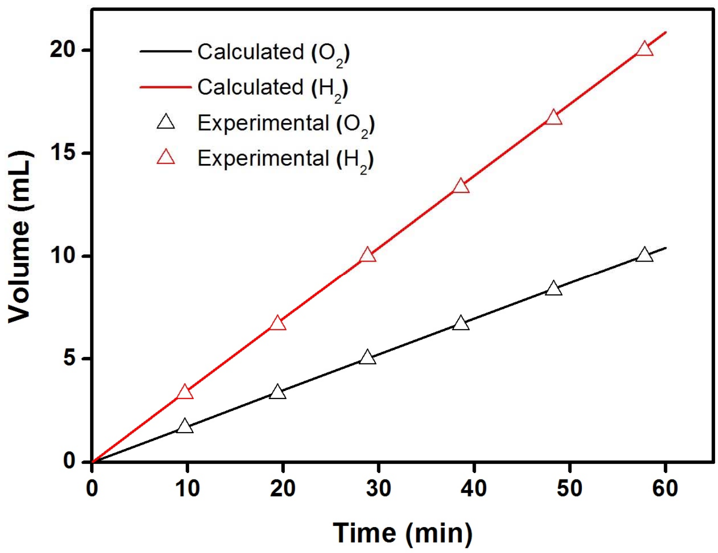

Figure S10. The amount of gas theoretically calculated and experimentally measured versus time of overall water splitting on MoS_2/Ni_3S_2 HNRs/NF.

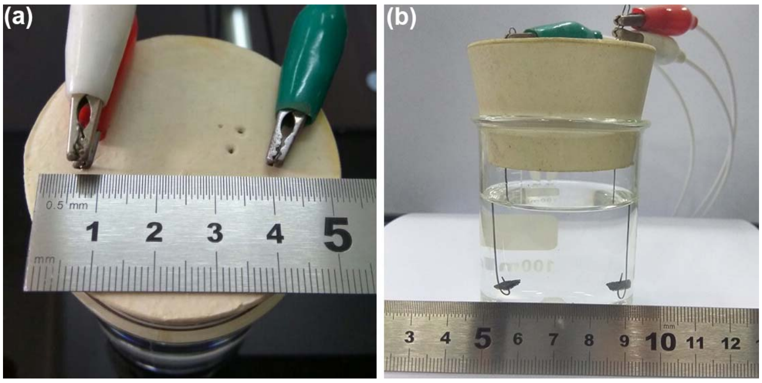

Figure S11. Photograph of the setup used for overall water splitting.

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