

Supporting Information

Pencil-like Hollow Carbon Nanotubes Embedded CoP-V₄P₃ Heterostructures as a Bifunctional Catalyst for Electrocatalytic Overall Water Splitting

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SEM images of CoVO

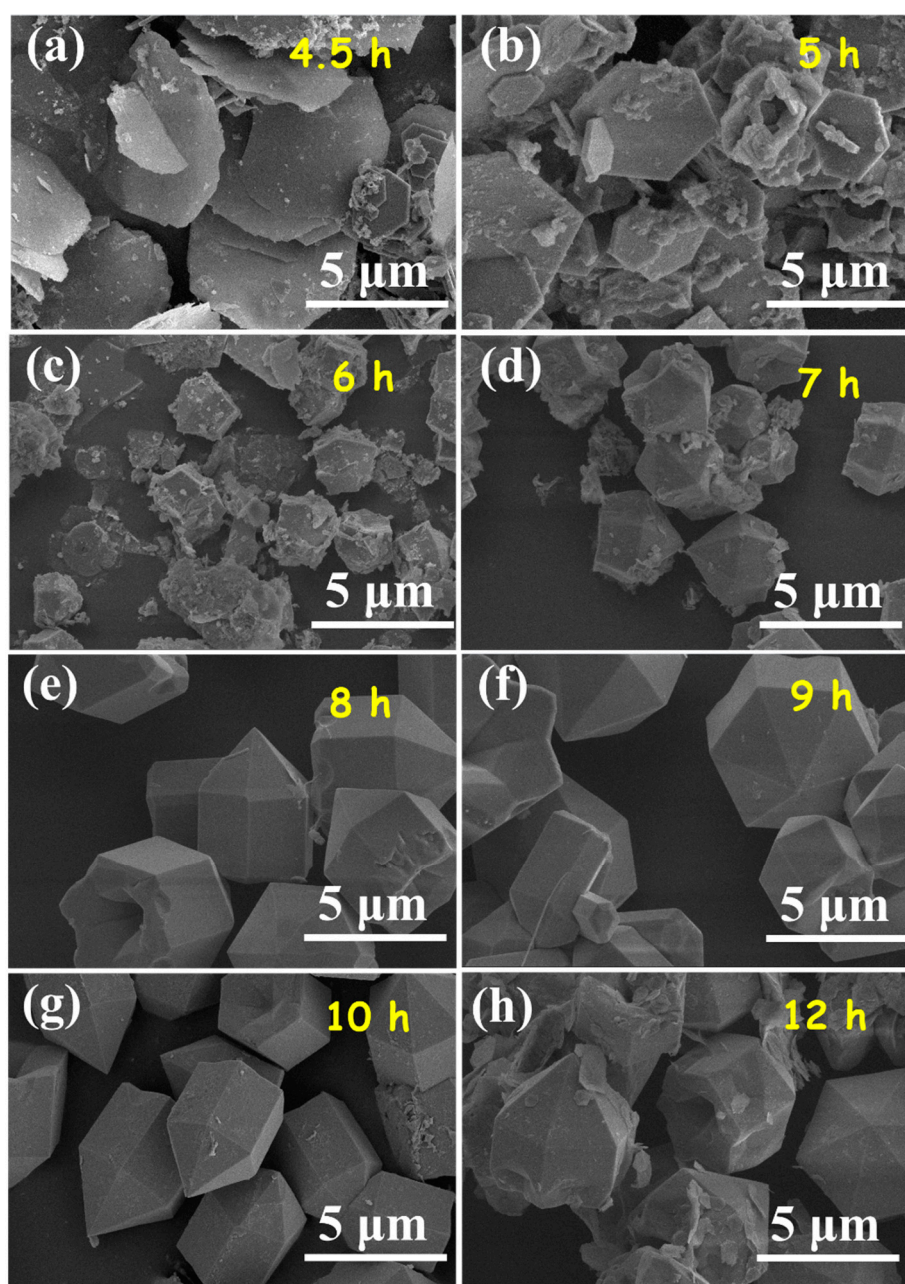


Figure S1. SEM images of CoVO synthesized by different hydrothermal reaction times.

SEM images of CoVO-10-CNT

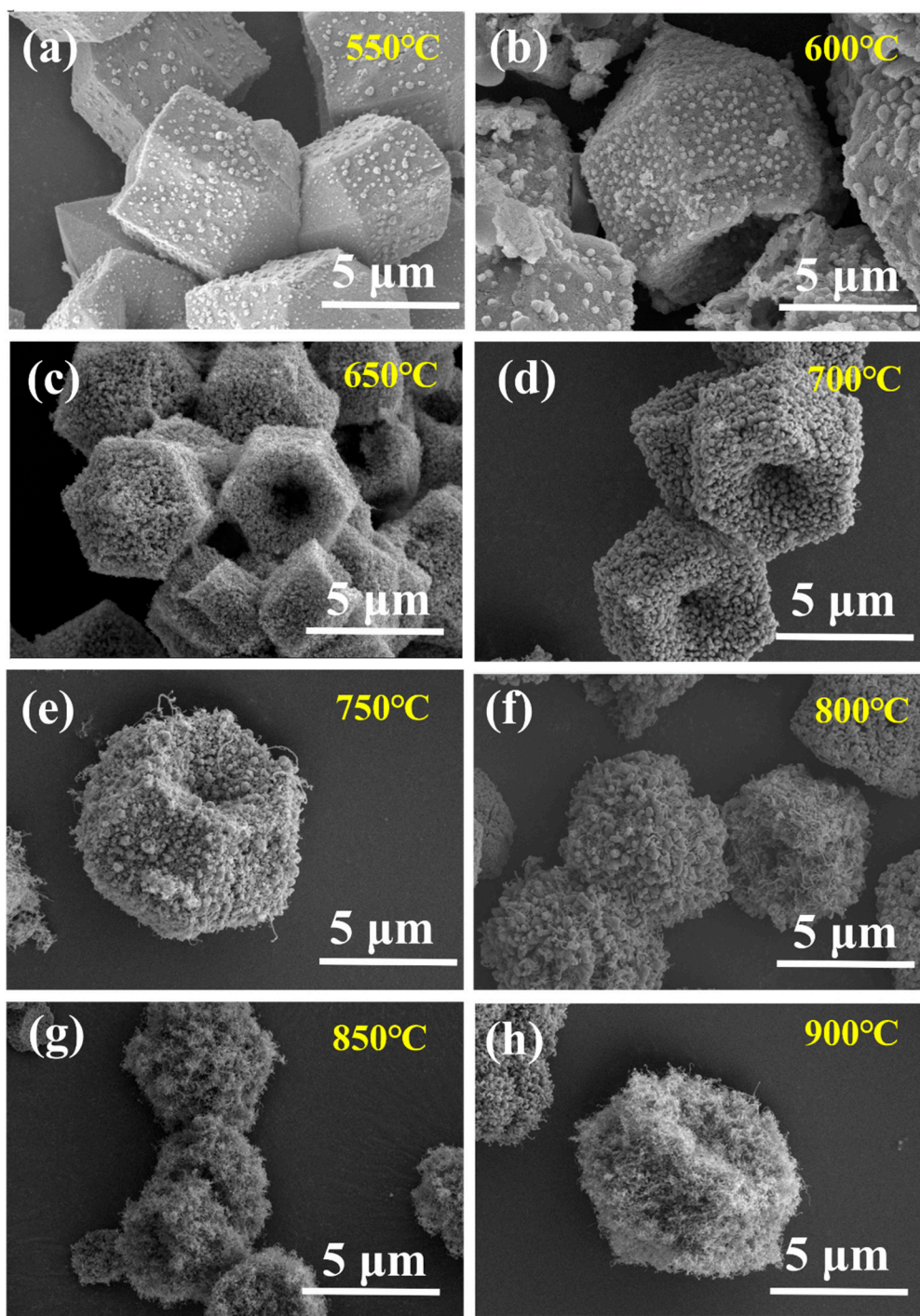


Figure S2. SEM images of CoVO-10-CNT synthesized by different vapor deposition calcination temperatures.

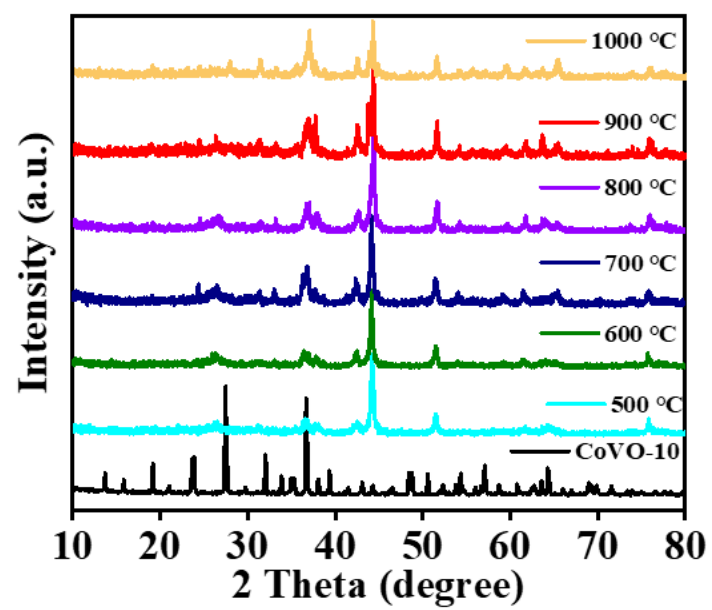


Figure S3. XRD patterns of the composites derived from CoVO-10 carbonized at different temperatures.

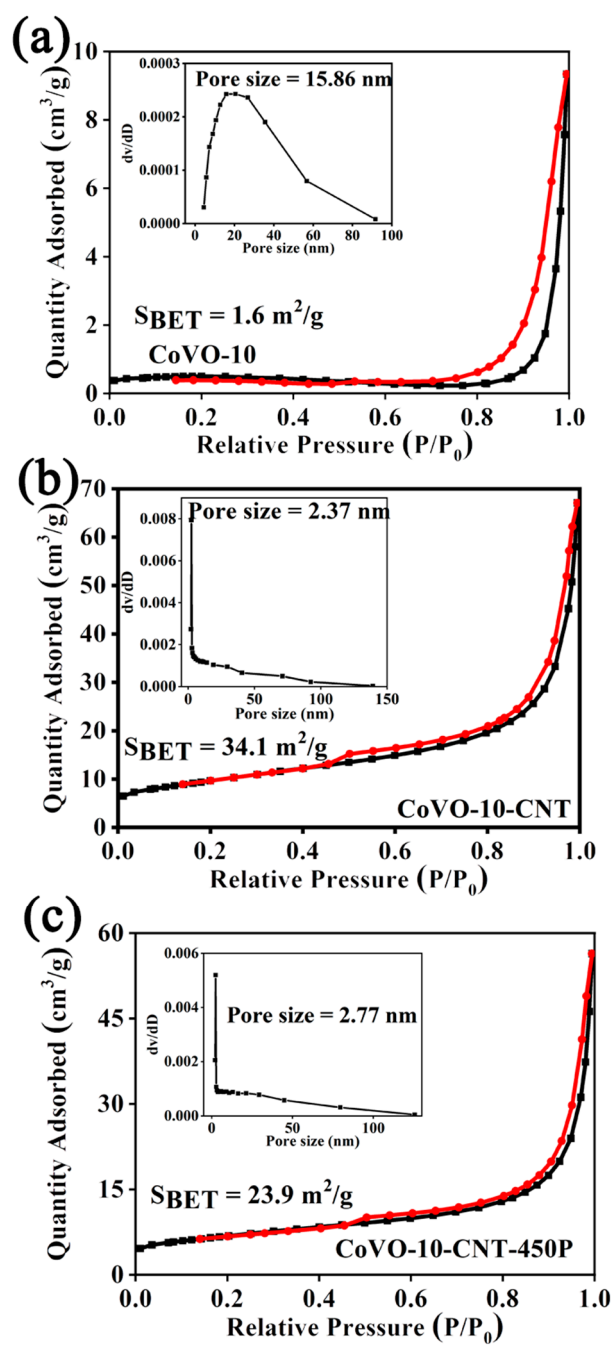


Figure S4. N₂ adsorption-desorption isotherms and corresponding BET surface areas of (a) CoVO-10, (b) CoVO-10-CNT and (c) CoVO-10-CNT-450P. The illustration shows the pore size distribution of the corresponding sample.

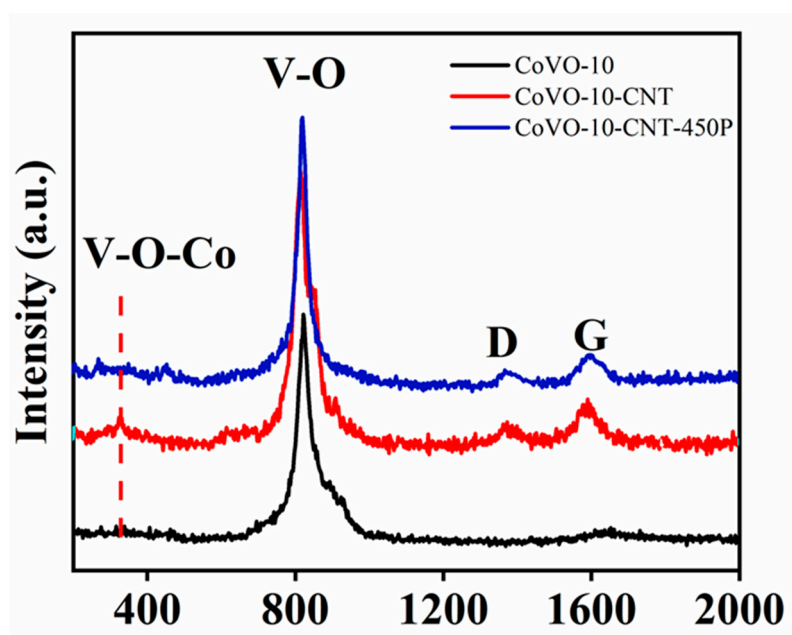


Figure S5. Raman spectra of different samples.

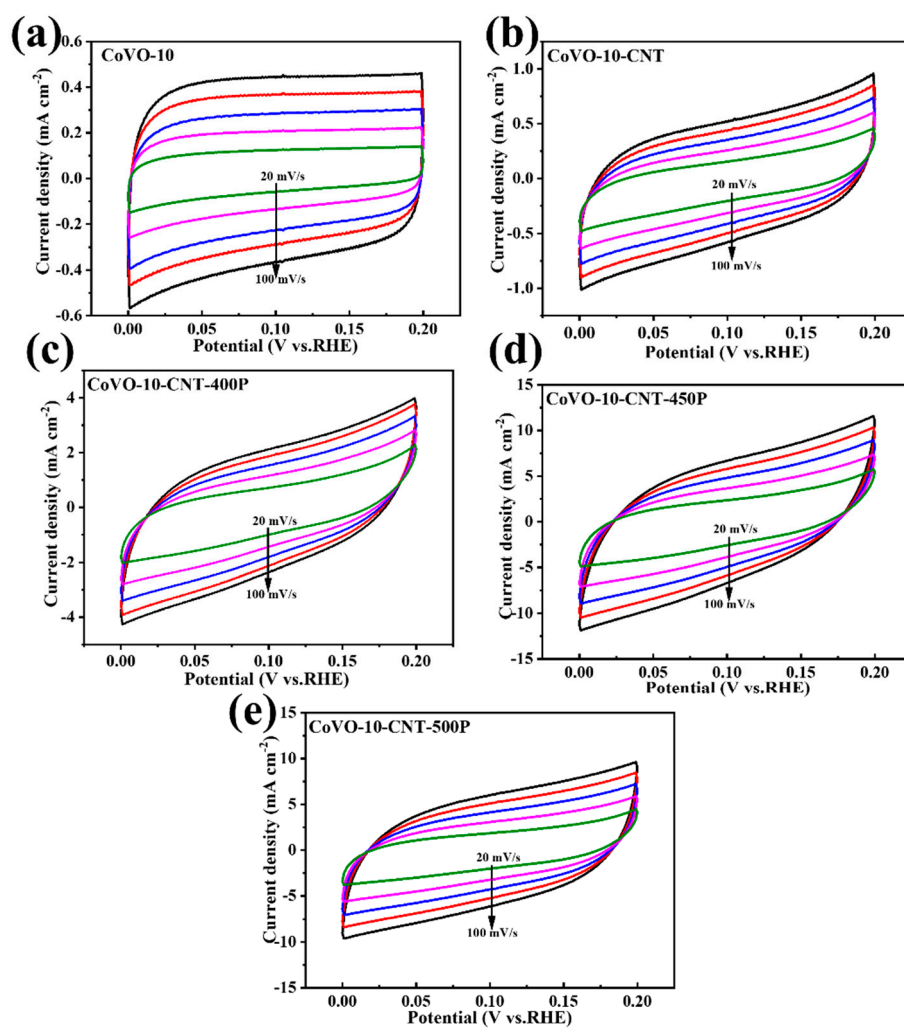


Figure S6. CV curves of different samples tested at 20–100 $\text{mV} \cdot \text{s}^{-1}$ in the potential range of 0–0.2V.

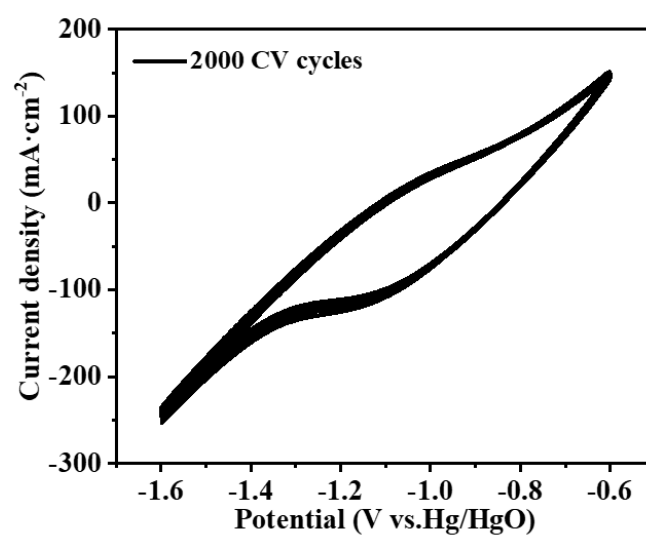


Figure S7. CV cycles of CoP/V₃P₄-CNT tested at the potential range of -1.6~-0.6 V.

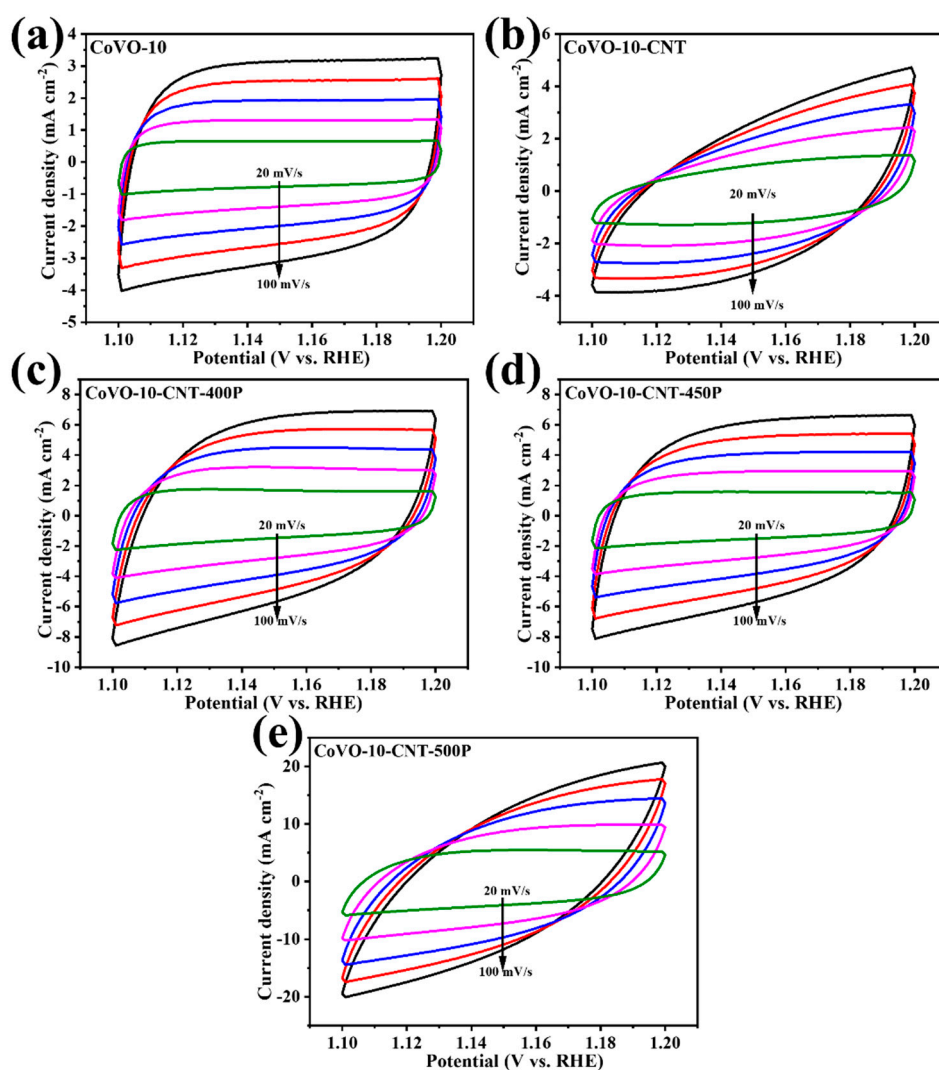


Figure S8. CV curve of different catalysts tested at 20–100 mV^{-1} in the potential range of 1.1–1.2 V.

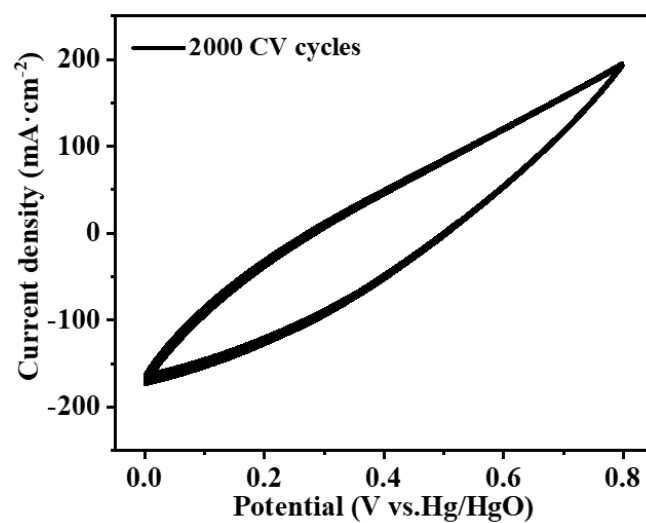


Figure S9. CV cycles of CoP/V₃P₄-CNT test in the potential range of 0–0.8 V.

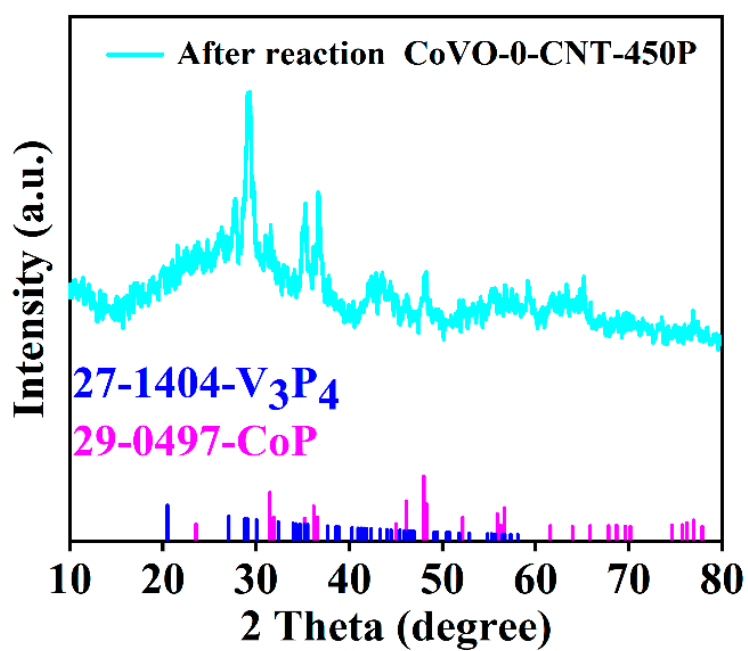


Figure S10. XRD pattern of CoVO-10-CNT-450P after stability test.

SEM images of CoVO-10-CNT-450P

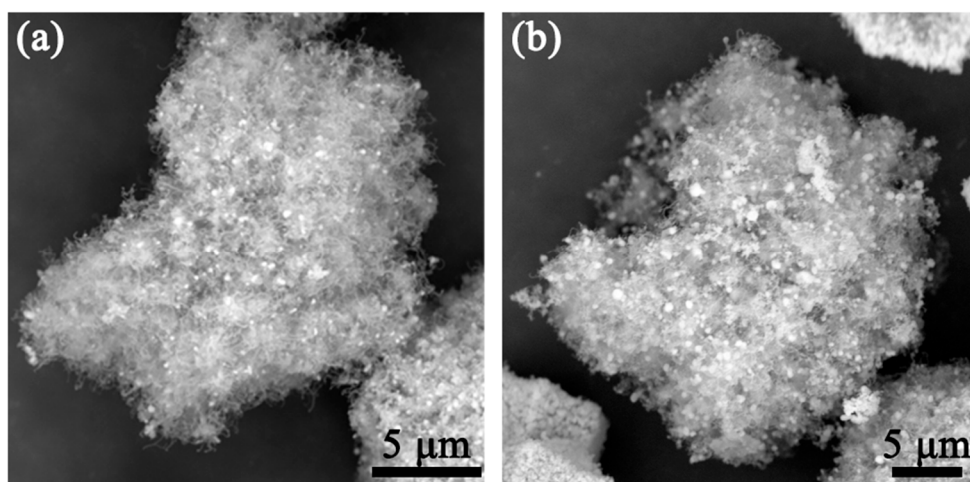


Figure S11. (a,b) SEM images of CoVO-10-CNT-450P after stability test.

XPS analyses of CoVO-10-CNT and CoVO-10-CNT-450P

Table S1. The element contents of Co, V, O, C and P elements in CoVO-10-CNT CoVO-10-CNT-450P determined by XPS analyses.

Sample	Content	Co	V	O	C	P
CoVO-10-CNT	At%	8.98	6.84	29.35	54.83	0
CoVO-10-CNT-450P	At%	8.38	6.84	27.20	52.49	5.09

Table S2. The resistance values for HER calculated from the EIS results of Figure 5e.

Catalyst	CoVO-10	CoVO-10- CNT	CoVO-10- CNT-400P	CoVO-10- CNT-450P	CoVO-10- CNT-500P
$R_s (\Omega)$	1.38	1.62	1.41	1.32	1.58
$R_{ct}(\Omega)$	8.05	5.27	4.11	2.63	3.12

Table S3. The resistance values for OER calculated from the EIS results of Figure 6e.

Catalyst	CoVO-10	CoVO-10- CNT	CoVO-10- CNT-400P	CoVO-10- CNT-450P	CoVO-10- CNT-500P
$R_s (\Omega)$	2.06	1.62	1.41	1.32	1.58
$R_{ct}(\Omega)$	16.35	11.68	9.69	5.85	7.16

Table S4. Performance comparison of recent non-noble metal bifunctional HER and OER electrocatalysts tested in 1.0 M KOH electrolyte.

Catalyst	$\eta_{\text{HER}}/\text{mV vs. RHE}$	$\eta_{\text{OER}}/\text{mV vs. RHE 10}$	References
	$10 \text{ mA} \cdot \text{cm}^{-2}$	$\text{mA} \cdot \text{cm}^{-2}$	
CoNi/MnO@CNTs	166	275	[13]
Co ₃ O ₄ @NiFe-LDH	79	215	[6]
Co _{5.47} N NP@N-PC	149	284	[2]
CoFe LDH-F/NF	166	260	[4]
Zn-Co-S	234	320	[11]
nanoneedle/CFP			
p-CoSe ₂ /CC	138	243	[9]
CoMo-LDH	115	290	[1]
CoP NS/CC	90	310	[14]
CoP ₃ NAs/CFP	119	334	[10]
Cu _{0.3} Co _{2.7} P/NC	220	190	[8]
CoP@SNC	174	350	[7]
CoP film	94	345	[3]
Ni _x Co _{3-x} S ₄ /Ni ₃ S ₂ /NF	136	160	[12]
CoS ₂ HNSs	193	290	[5]
CoP/V₃P₄-CNT	124	280	This work

Table S5. Comparison the overall water splitting performance of CoVO-10-CNT-450P with previous reported superior bifunctional electrocatalysts tested in 1.0 M KOH.

Catalytic material	Voltage@10 mA cm ⁻²	Ref.
NiFeS@MXene/NF	1.57	[15]
Ni-Co-S film/Cu foam	1.67	[16]
NiFeRu-LDH	1.52	[17]
NiFe/NiCo ₂ O ₄ /Ni foam	1.67	[18]
Cu ₃ P NS/Ni foam	1.67	[19]
Mo ₂ C@C nanosheets	1.73	[20]
FeCo/Carbon paper	1.68	[21]
CoVO-10-CNT-450P	1.66	This work

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