Supporting Information

Ru and Se Co-Doped Cobalt Hydroxide Electrocatalyst for Efficient Hydrogen Evolution Reactions

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OER and HER mechanism

The steps of OER primitives under alkaline conditions are as follows [1]:

$$OH^- + * \rightarrow OH_{ads} + e^- \quad (1)$$

$$OH_{ads} + OH^- \rightarrow O_{ads} + H_2O + e^- \quad (2)$$

$$O_{ads} + OH^- \rightarrow OOH_{ads} + e^- \quad (3)$$

$$OOH_{ads} + OH^- \rightarrow O_{2ads} + H_2O + e^- \quad (4)$$

$$O_{2ads} \rightarrow O_2 + * \quad (5)$$

$$\text{Overall: } 4OH^- \rightarrow 2H_2O + O_2 + 4e^-$$

The steps of OER primitives under acidic conditions are as follows:

$$H_2O + * \rightarrow OH_{ads} + H^+ + e^- \quad (1)$$

$$OH_{ads} \rightarrow O_{ads} + H^+ + e^- \quad (2)$$

$$O_{ads} + H_2O \rightarrow OOH_{ads} + H^+ + e^- \quad (3)$$

$$OOH_{ads} \rightarrow O_{2ads} + H^+ + e^- \quad (4)$$

$$O_{2ads} \rightarrow O_2 + * \quad (5)$$

$$\text{Overall: } 2H_2O \rightarrow 4H^+ + O_2 + 4e^-$$

where the * represents the active sites on the catalyst surface, and the "ads" represents adsorbed state of intermediates (OH_{ads}, O_{ads}, OOH_{ads}, and O_{2ads}).

The steps of HER primitives under alkaline conditions are as follows:

$$H_2O + e^- \rightarrow OH^- + H_{ads} \text{ (Volmer) } (1)$$

$$H_{ads} + H_2O + e^- \rightarrow OH^- + H_2 \text{ (Heyrovsky) } (2)$$

$$\text{or } 2H_{ads} \rightarrow H_2 \text{ (Tafel) } (3)$$

The steps of HER primitives under acidic conditions are as follows:

$$H^+ + e^- + * \rightarrow H_{ads} \text{ (Volmer) } (1)$$

$$H_{ads} + H^+ + e^- \rightarrow H_2 \text{ (Heyrovsky) } (2)$$

$$\text{or } 2H_{ads} \rightarrow H_2 \text{ (Tafel) } (3)$$

where the * represents the active sites on the catalyst surface, and the "ads" represents adsorbed state of intermediates (H_{ads}).

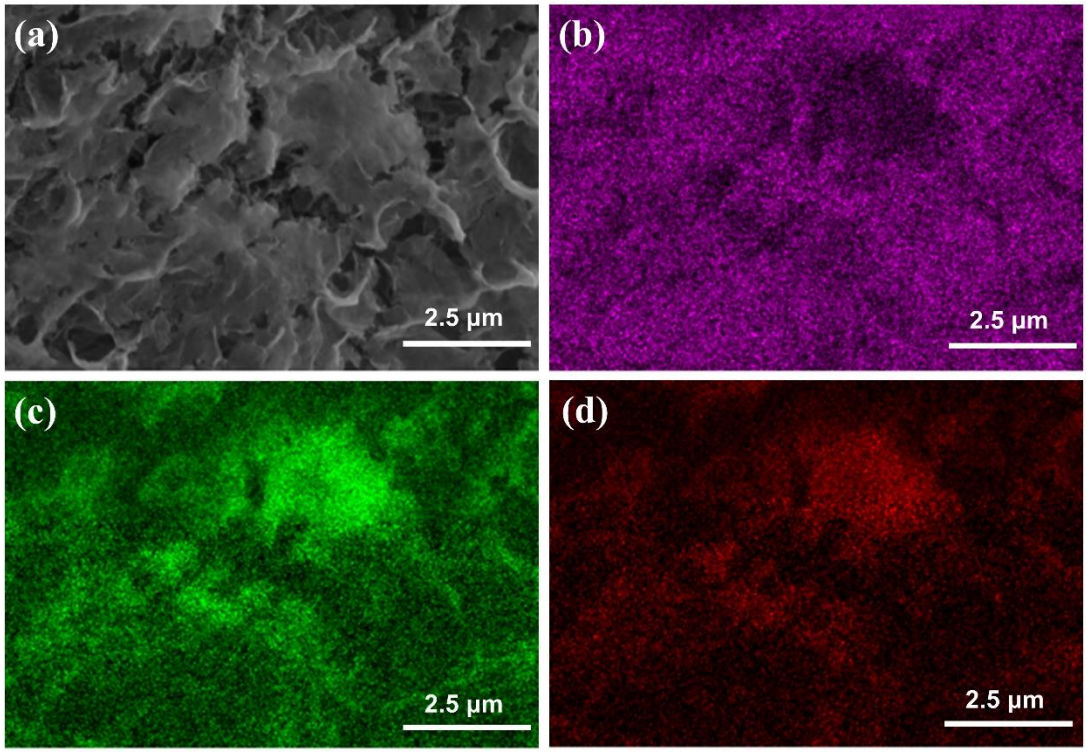

Figure S1. (**a**) SEM image of Ru-Co(OH)$_2$-Se. EDS elemental mapping images of (**b**) Co, (**c**) Se, (**d**) Ru.

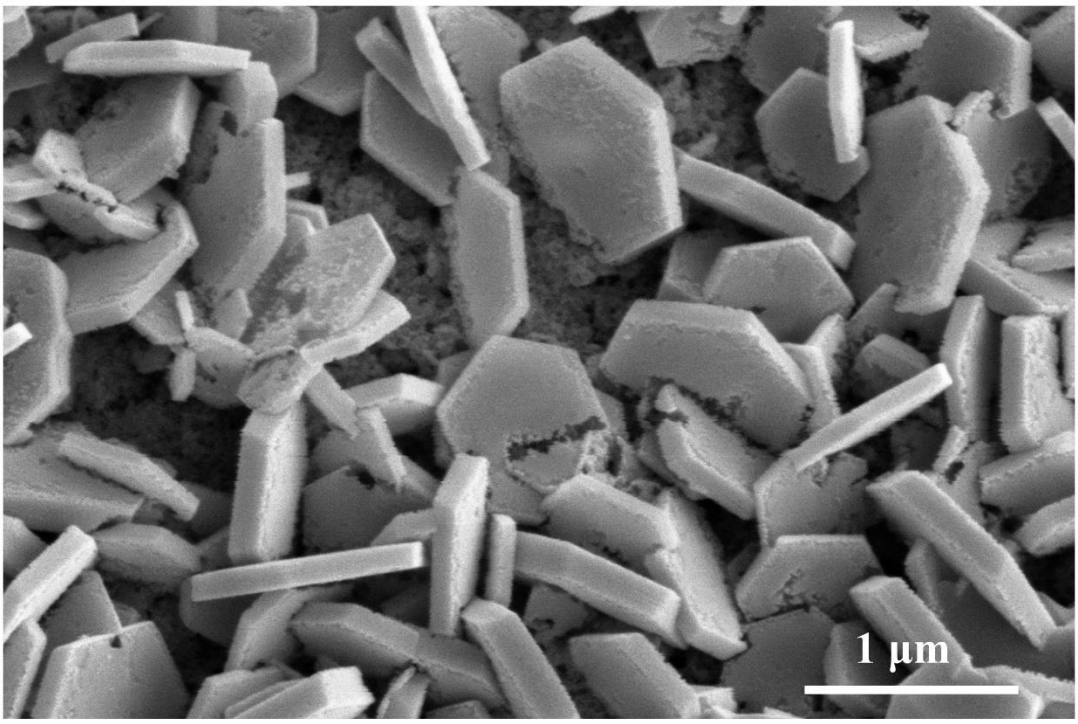

Figure S2. SEM image of post-HER Ru-Co(OH)$_2$-Se.

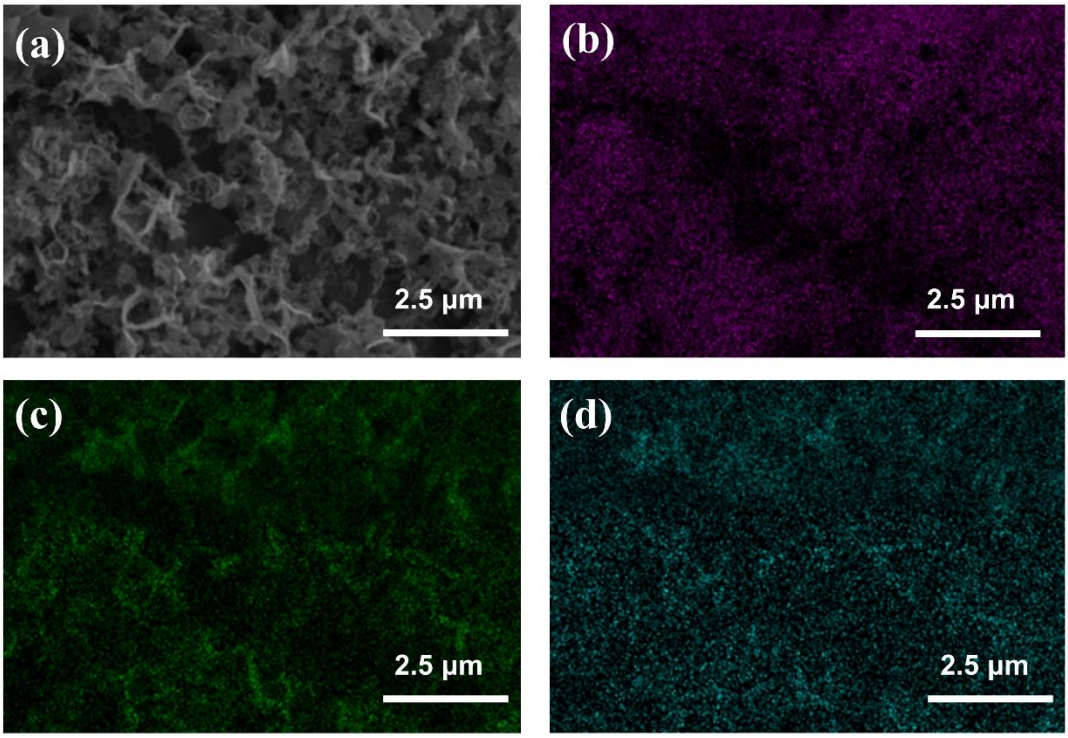

Figure S3. (**a**) SEM image of post-HER Ru-$Co(OH)_2$-Se. EDS elemental mapping images of (**b**)Co, (**c**)Se, (**d**)Ru.

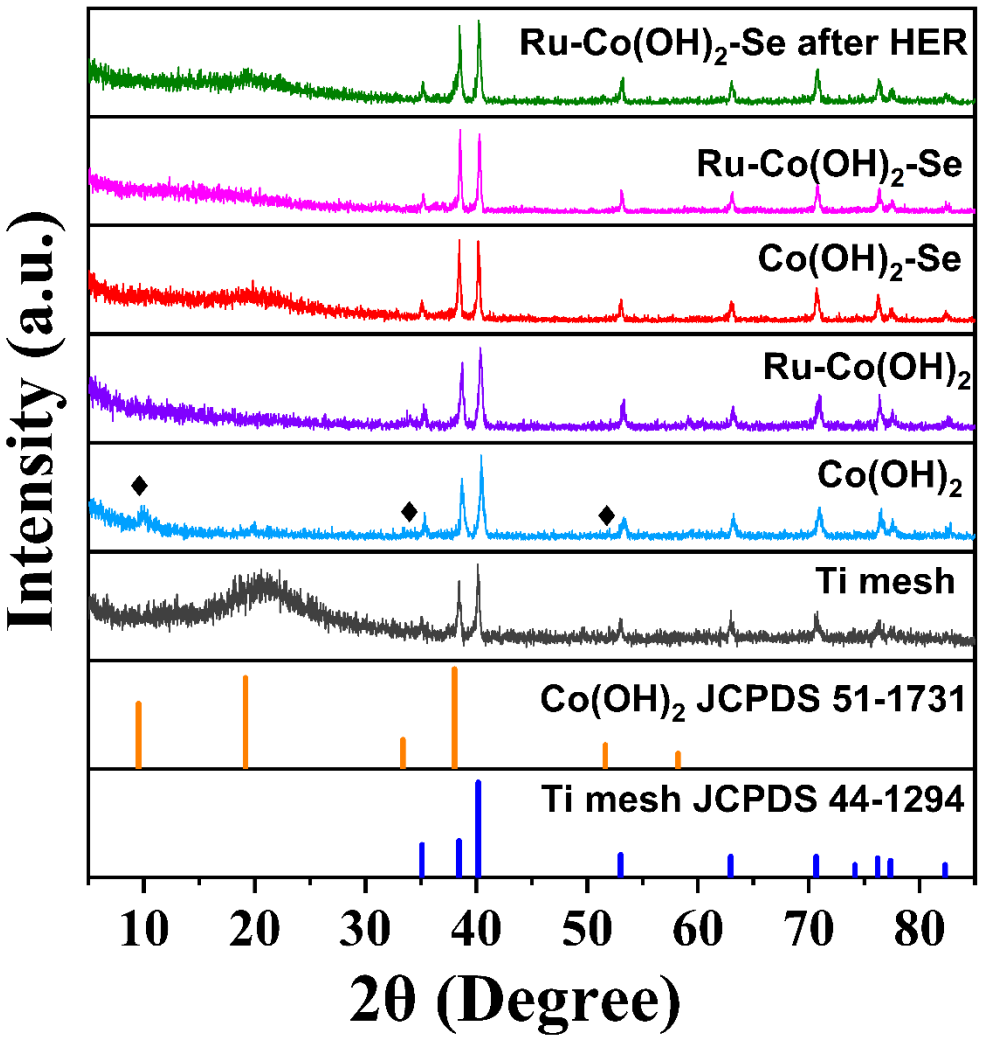

Figure S4. X-ray diffraction (XRD) patterns of each electrode material.

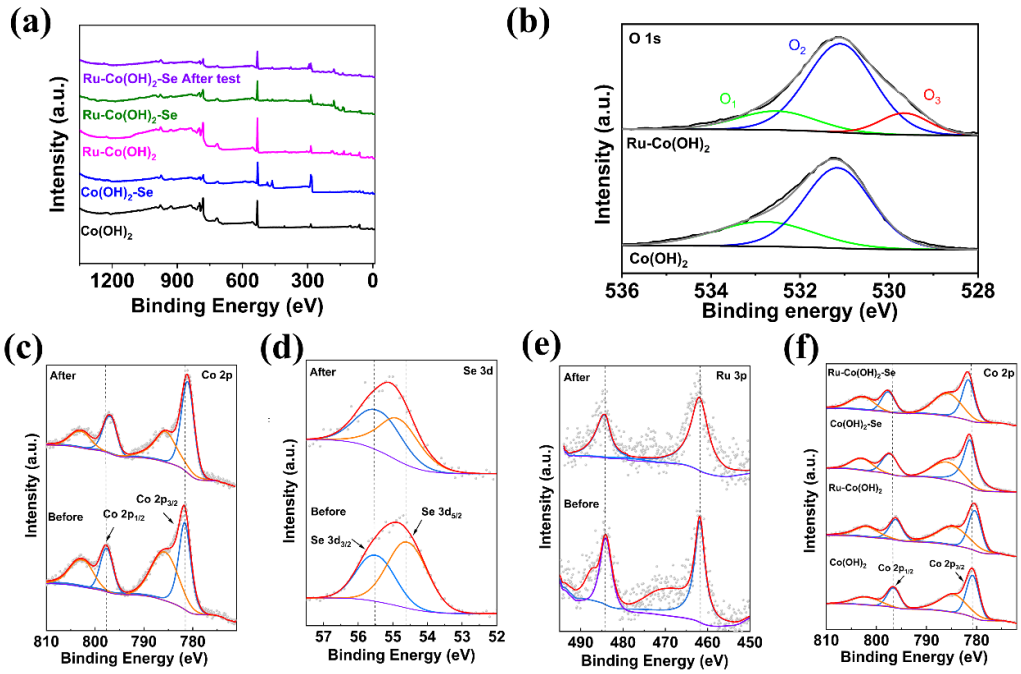

Figure S5. (**a**) XPS spectra of the electrode material, (**b**) O 1s spectrum, (**c**) Co 2p spectrum, (**d**) Se 3d spectrum, (**e**) Ru 3p spectrum, (**f**) Co 2p spectrum in four materials.

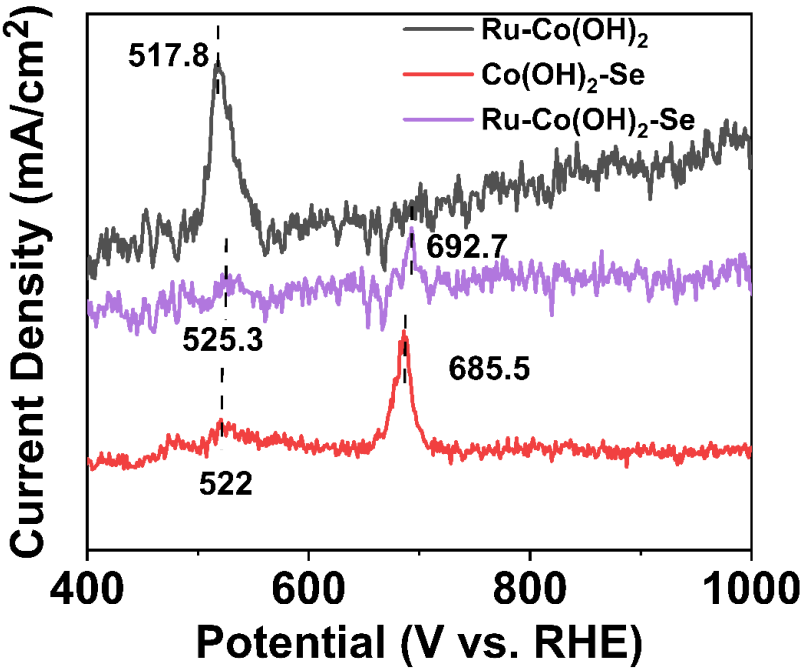

Figure S6. Raman spectroscopy of the electrode material.

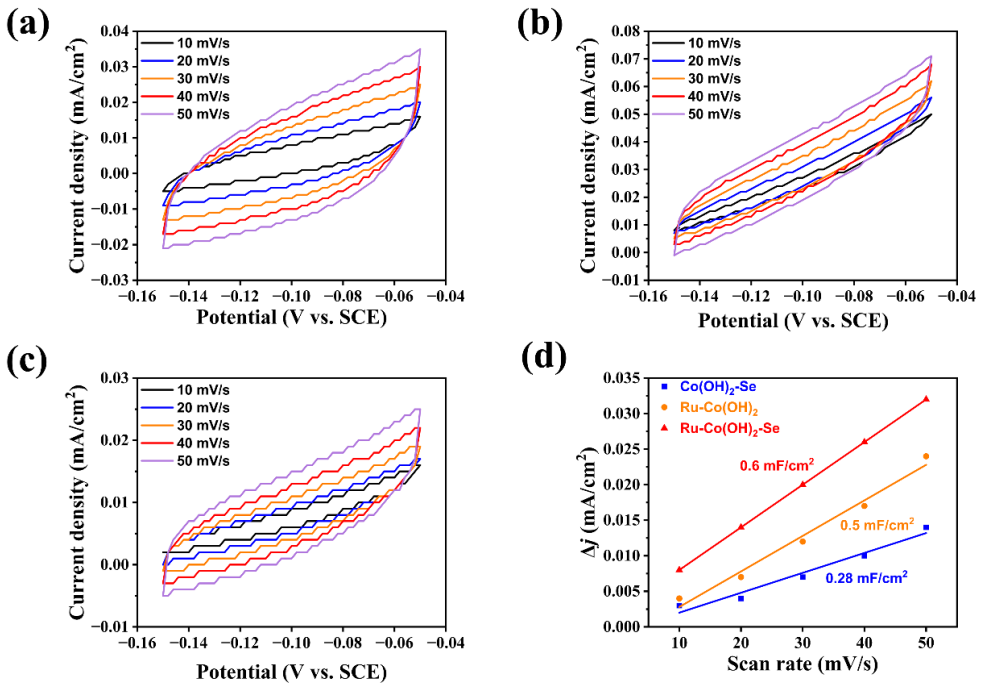

Figure S7. The CV curves of (**a**) Ru-Co(OH)$_2$-Se, (**b**) Ru-Co(OH)$_2$, (**c**) Co(OH)$_2$-Se catalyst materials at different scan rates.(**d**) The current density change value and the scanning rate of the three catalyst materials.

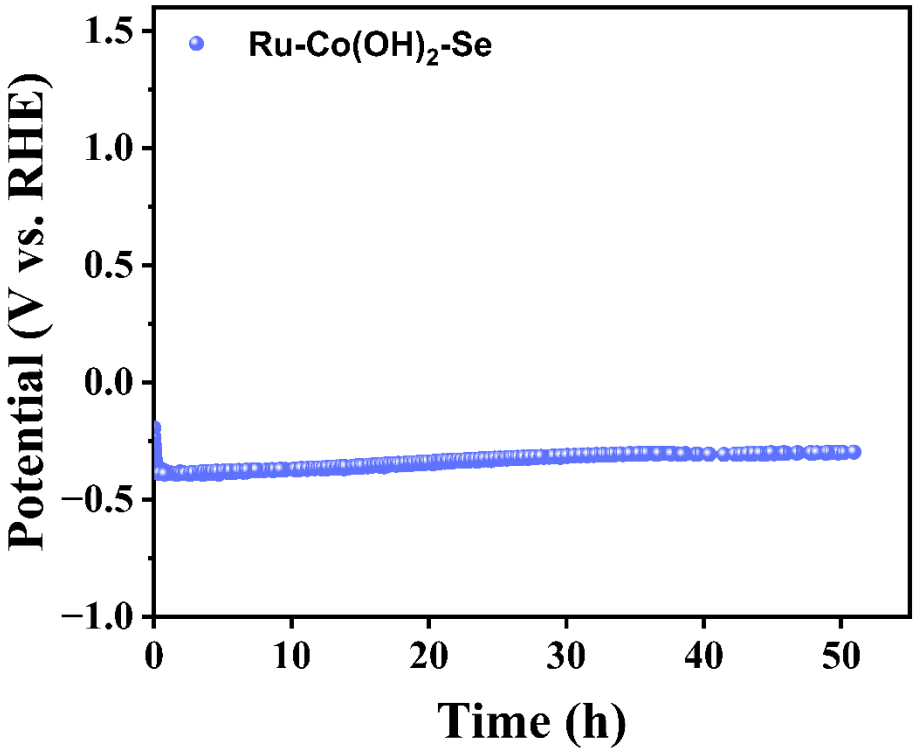

Figure S8. Timing potential curve of Ru-Co(OH)$_2$-Se for 50 hours in 30 wt% KOH solution.

Table S1. The content of Co, Se, Ru elements in Ru-Co(OH)$_2$-Se.

Element	Wt %	σ	Mol %
Co	64.7	0.1	0.27
Se	27.8	0.1	0.12
Ru	7.6	0.1	0.03

Table S2. pH value of 1M KOH.

1M KOH	Measured Value	Theoretical Value
pH value	13.77	14

1. Li, Z.; Li, B.; Yu, M.; Yu, C.; Shen, P. Amorphous metallic ultrathin nanostructures: A latent ultra-high-density atomic-level catalyst for electrochemical energy conversion. *Int. J. Hydrogen. Energy* **2022**, doi:10.1016/j.ijhydene.2022.06.049.