

Supporting information

Nanostructured RuO₂-Co₃O₄@RuCo-EO with low Ru loading as a high-efficiency electrochemical oxygen evolution catalyst

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Experimental section

Treatment of Ti substrate

The titanium plate was first sandblasted and then ultrasonically clean in acetone, ethanol and ultrapure water for 10 minutes. This process is repeated several times to remove all surface impurities. The Ti plate processed above was placed on the sample stage of the vacuum chamber.

Preparation of RuO₂/Ru electrode

During the experiment, a Ru target with a purity of 99.99% was used as sputtering targets. Evacuate the vacuum chamber to 4×10^{-4} Pa before sputtering. Then high-purity Ar gas was introduced, and the flow rate of argon gas was 30 mL min^{-1} . Adjust the pressure of the vacuum chamber to $1.0 \sim 1.2$ Pa, and then the Ru target was connected to the DC power supply. The sputtering power of the Ru target was 60 W and the sputtering time is 10 min. After the sputtering was completed, the resulting sample was recorded as the Ru catalyst. Next, it was calcined in a muffle furnace at 400°C for 2 h, and the resulting sample was recorded as the RuO₂/Ru catalyst.

Preparation of RuO₂ electrode

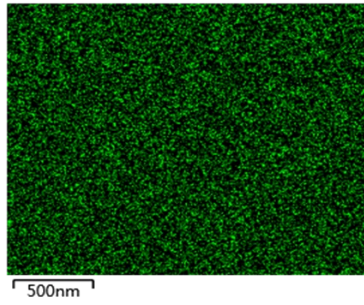
During the experiment, a Ru target with a purity of 99.99% was used as sputtering targets. Evacuate the vacuum chamber to 4×10^{-4} Pa before sputtering. Then high-purity Ar and O₂ gas was introduced. The flow rate of argon and O₂ gas was 24 and 6 mL min^{-1} , respectively. Adjust the pressure of the vacuum chamber to $1.0 \sim 1.2$ Pa, and then the Ru target was connected to the DC power supply. The sputtering power of the Ru target was 60 W and the sputtering time is 10 min. Next, it was calcined in a muffle furnace at 400°C for 2 h, and the resulting sample was recorded as the RuO₂ catalyst.

Preparation of RuO₂-T electrode

RuCl₃·xH₂O solid was dissolved in the mixed solution of isopropanol and ethanol (the volume ratio of isopropanol to ethanol was 1:1), and its ion concentration was 0.02 mol L^{-1} . $5 \mu\text{L}$ of the solution was dripped on a 1 cm^2 Ti plate, then dried in an oven at 120°C for 10 min, and then oxidized at 450°C for 10 min in a muffle furnace. This process is repeated 6 times, and the last roasting time in muffle furnace is 1 h. Thereby obtaining the RuO₂ catalyst prepared by the thermal decomposition method and marked as RuO₂-T catalyst.



Ru L α 1



Co K α 1

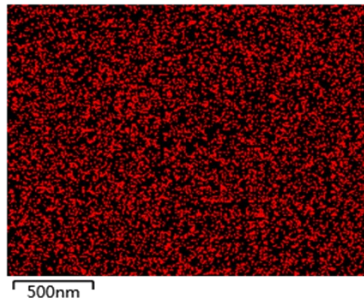


Figure S1 SEM mapping of RuO₂/Co₃O₄-RuCo electrode.

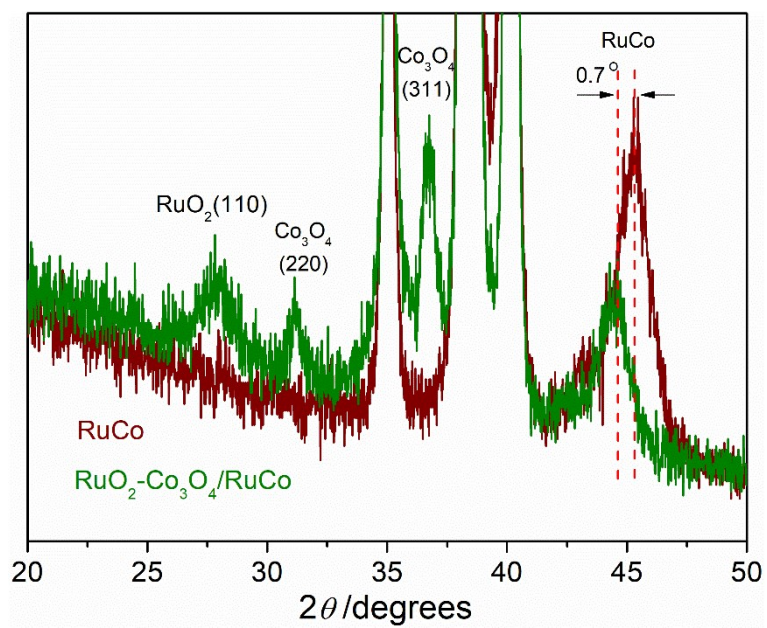


Figure S2 X-ray diffraction patterns of RuO₂/Co₃O₄-RuCo and RuCo electrodes.

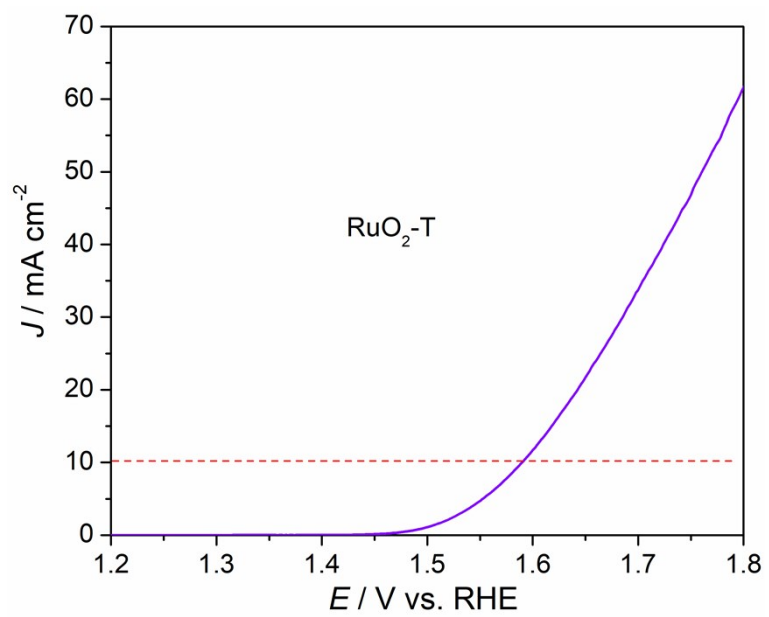


Figure S3 The OER activity of RuO₂-T electrode prepared by thermal decomposition.

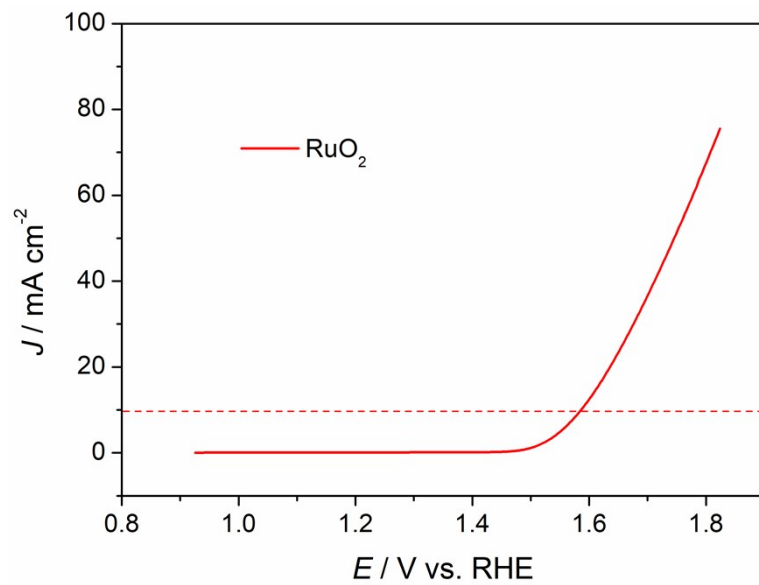


Figure S4 The OER activity of RuO_2 electrode prepared by magnetron sputtering.

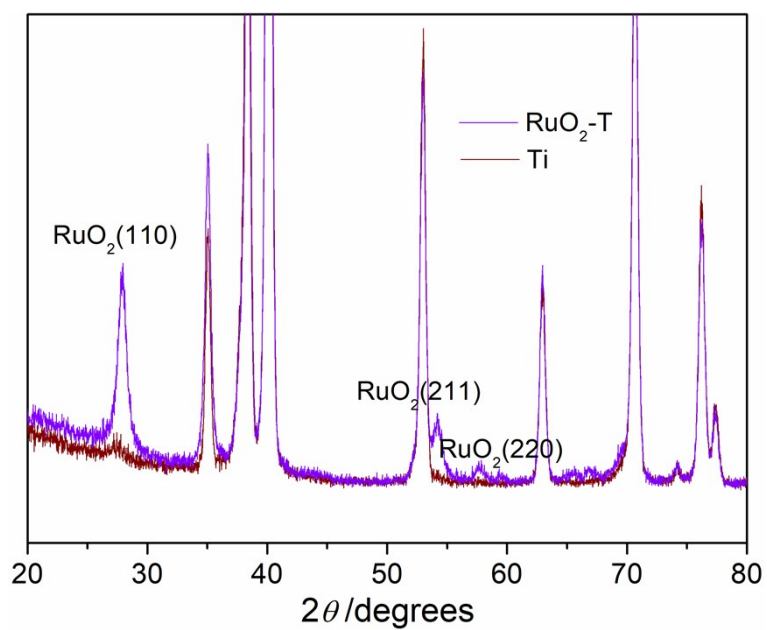


Figure S5 X-ray diffraction pattern of RuO₂-T electrode prepared by thermal decomposition.

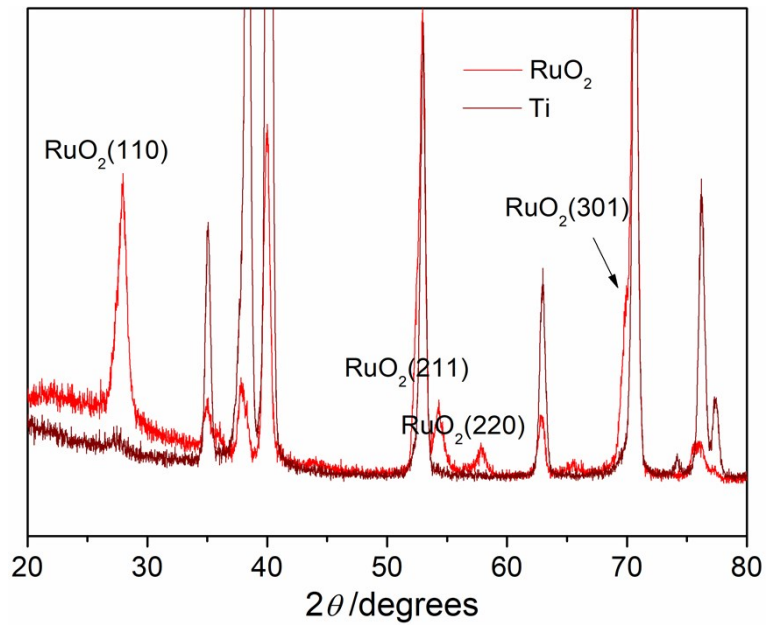


Figure S6 X-ray diffraction pattern of RuO₂ electrode prepared by magnetron sputtering.

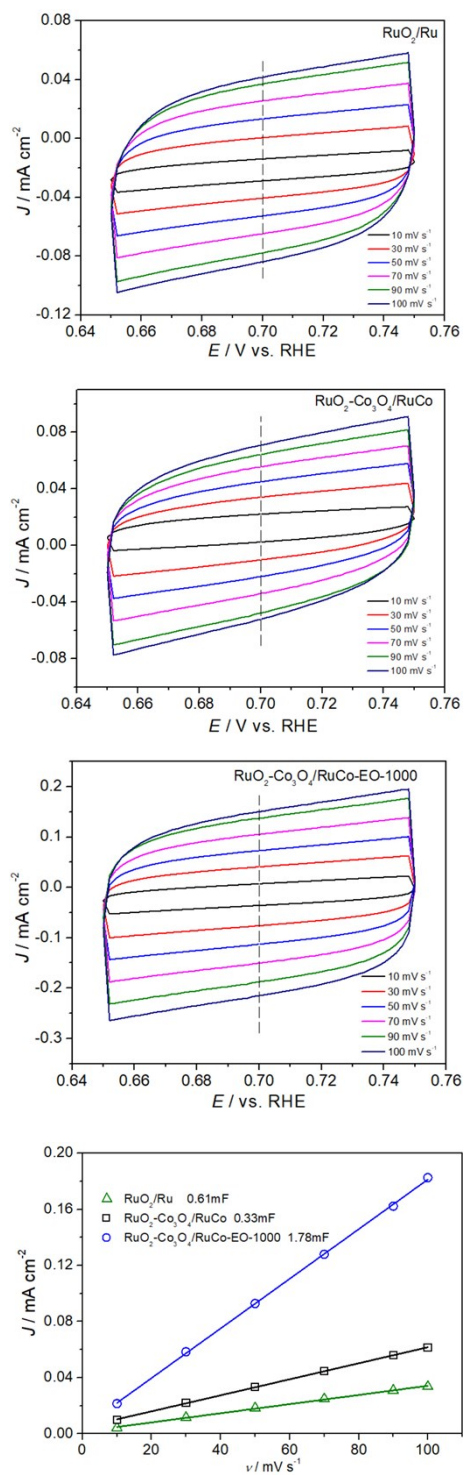


Figure S7 The double-layer capacitances of RuO₂/Ru, RuO₂/Co₃O₄-RuCo and RuO₂/Co₃O₄-RuCo-EO electrodes.

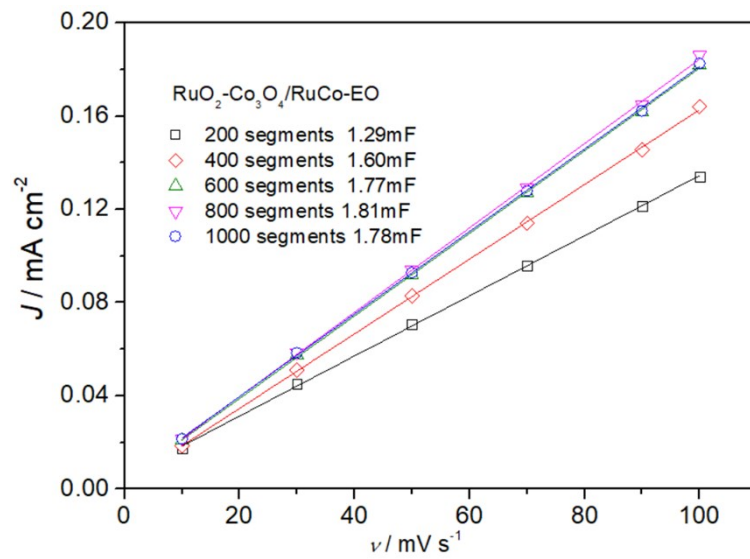


Figure S8 The double-layer capacitances of RuO₂/Co₃O₄-RuCo-EO electrodes with different number of CV scan.

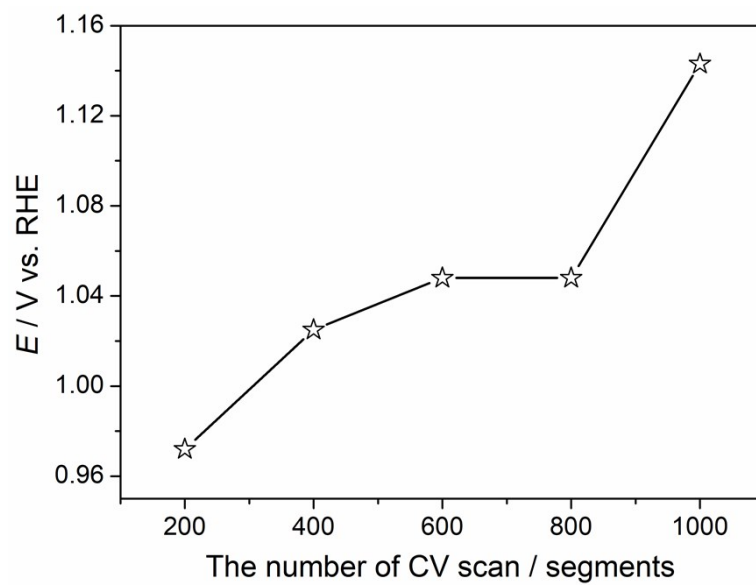


Figure S10 The relationship between the oxidation potential of Co and the number of CV scan

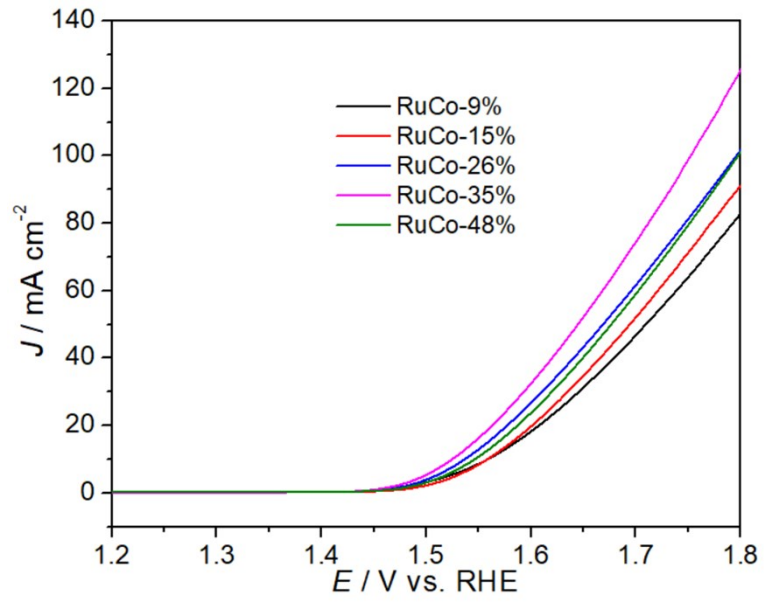


Figure S10 The OER activities of $\text{RuO}_2/\text{Co}_3\text{O}_4$ -RuCo-EO with different Co content.

When the sputtering power of Ru is fixed at 60 W and the sputtering power of Co is 20, 40, 60, 80, and 100 W, the corresponding Co molar ratios is 9, 15, 26, 35, and 48 % after EO treatment of 1000 segments, respectively.

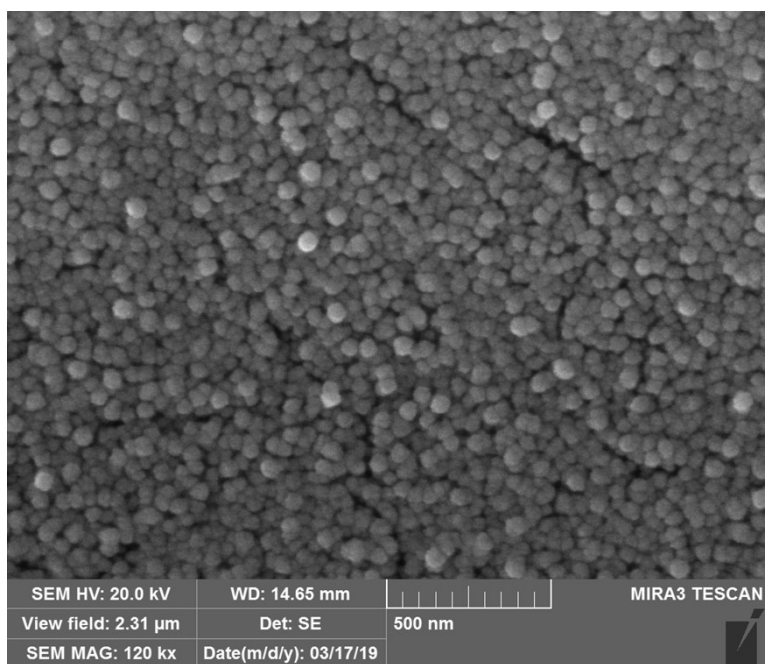


Figure S11 SEM image of RuO₂ electrode prepared by magnetron sputtering.

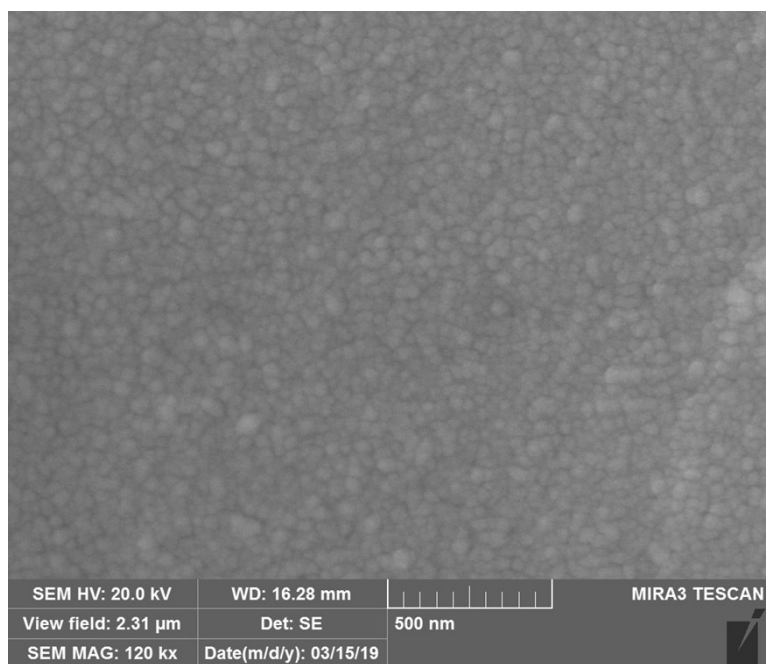


Figure S12 SEM image of RuO₂-T electrode prepared by thermal decomposition.

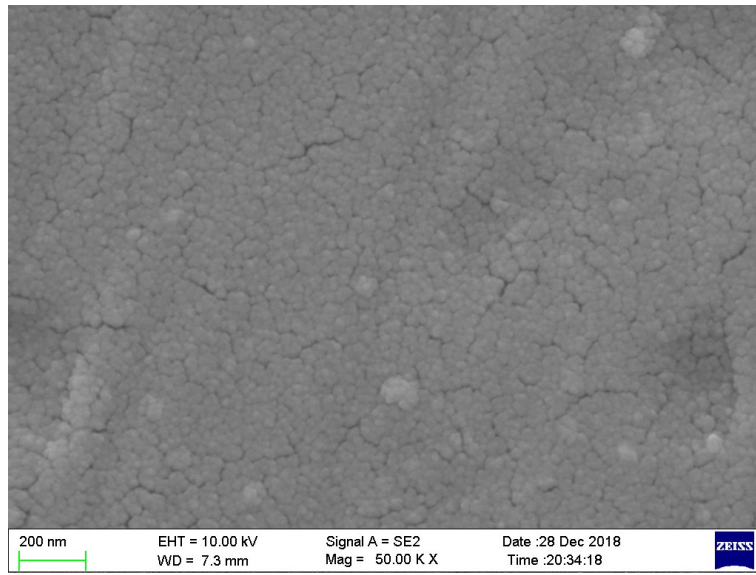


Figure S13 SEM image of RuO₂/Ru electrode prepared by magnetron sputtering.

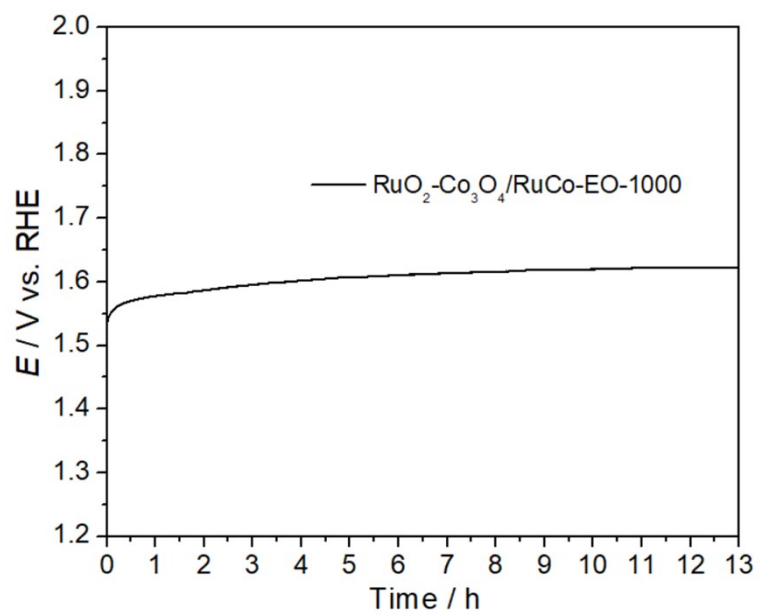


Figure S14 The OER stability of the RuO₂/Co₃O₄-RuCo-EO-1000 electrode.

Table S1 The molar ratio of Ru to Co of RuO₂-Co₃O₄/RuCo-EO electrode

CV scan (segments)	Ru:Co (mol:mol)
0	56:44
200	61:39
400	66:34
600	67:33
800	67:33
1000	65:35