

Enhancing Chlorine Evolution Performance of Ru-Based DSA Electrodes via Cobalt Incorporation for Direct Electrolysis of Seawater

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Supplementary Information (SI):

Table S1 Roughness data of samples with different titanium matrices

Samples	S _a / μm	S _q / μm	S _{sk}	Kurtosis	S _p / μm	S _v / μm	S _z / μm
Ti	0.77	1.03	1.12	1.64	4.88	3.82	8.69
Ti-HCl	3.51	4.48	0.40	0.63	28.50	24.40	52.89
Ti-H ₂ C ₂ O ₄	5.19	6.78	0.69	1.07	34.00	19.80	53.80

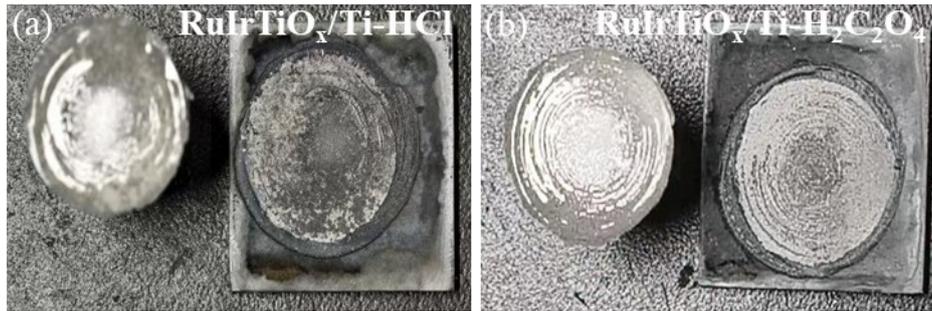


Fig. S1 the fracture morphology of RuIrTiO_x/Ti-HCl and RuIrTiO_x/Ti-H₂C₂O₄ after pull-off experiment.

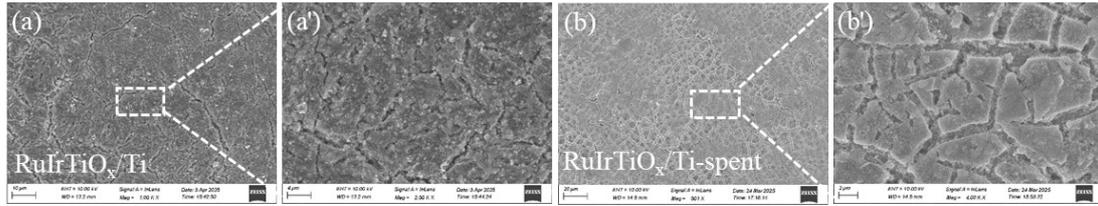


Fig. S2 The SEM images of RuIrTiO_x/Ti and RuIrTiO_x/Ti before and after accelerated lifetime experiment.

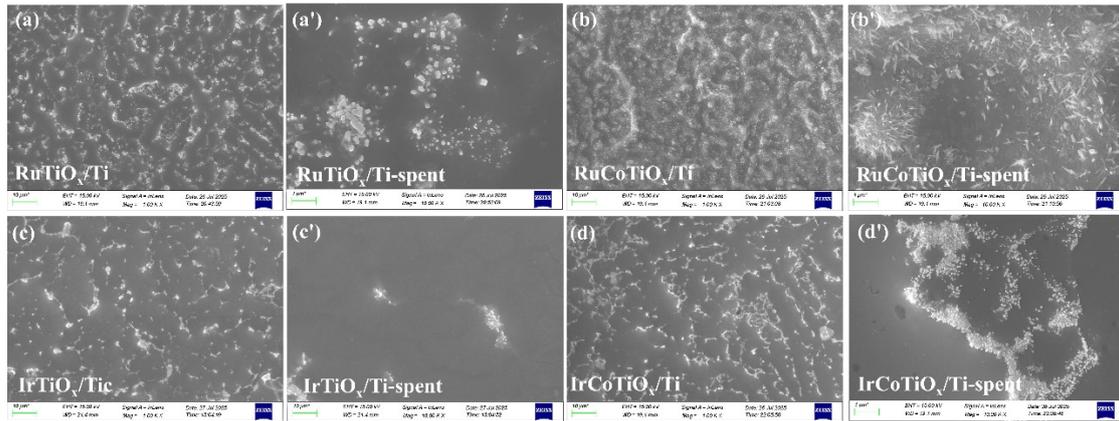


Fig. S3 The SEM images of RuTiO_x/Ti, RuCoTiO_x/Ti, IrTiO_x/Ti and IrCoTiO_x/Ti before and after accelerated lifetime experiment.

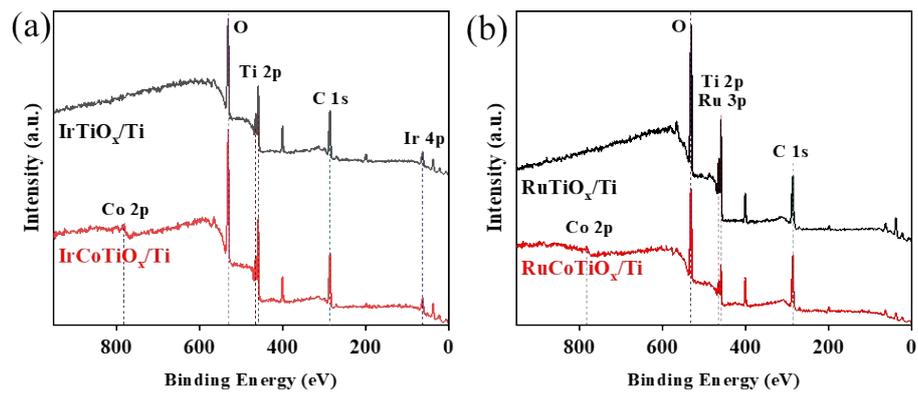


Fig. S4 The XPS total spectra of RuTiO_x/Ti, RuCoTiO_x/Ti, IrTiO_x/Ti and IrCoTiO_x/Ti.

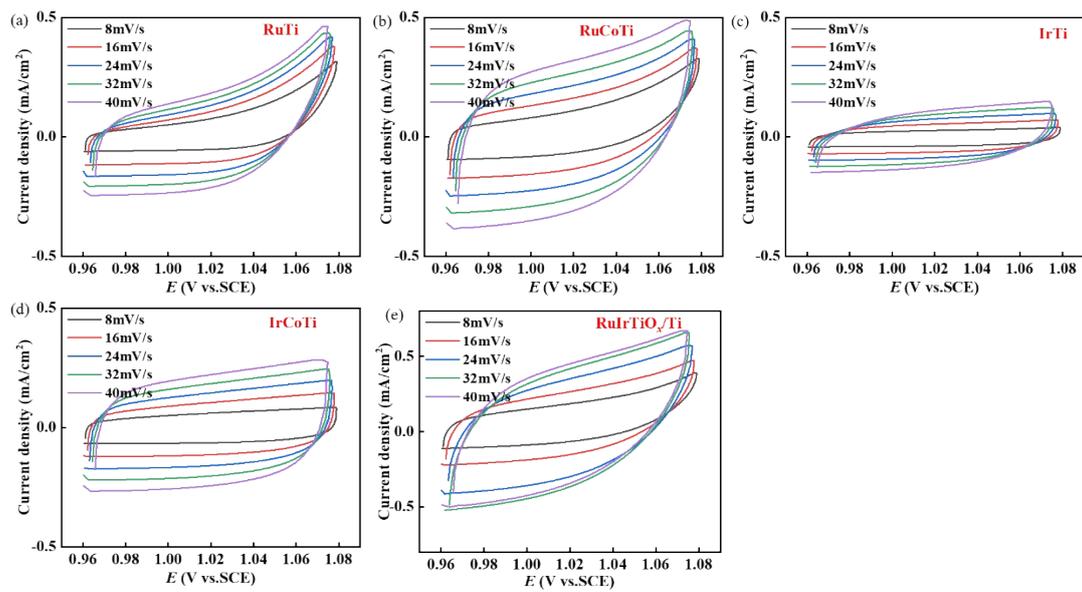


Fig. S5 The CV curves in saturated NaCl solution at different scan rates ranging from 8 to 40 mV s⁻¹.

Table S2 Types of reported anodes for electrolysis of seawater and their chlorine evolution selectivity

Electrocatalysts	Operating conditions	Current efficiency (%)	Ref.
RuIrCoTiO _x /Ti	3.5wt% NaCl	84.3%	This work
RuO ₂ /TiO ₂	10mA/cm ² 0.6M NaCl	82%	<i>Trends in Chemistry</i> , 2021, 3 , 485-498.
DSA1	10mA/cm ² 0.6M NaCl	78%	<i>J. Phys. Chem. Lett.</i> , 2019, 10 , 1226-1233.
Ti/RuO ₂ -Sb ₂ O ₅ -SnO ₂	10mA/cm ² 0.5M Na ₂ SO ₄ + seawater	80%	<i>Chem. Eng. J.</i> , 2011, 172 , 47-51.
Ti/RuO ₂ -IrO ₂ -Sb ₂ O ₅ -SnO ₂	seawater	71.2%	<i>Electrochemistry</i> , 2012, 80 , 507-511.

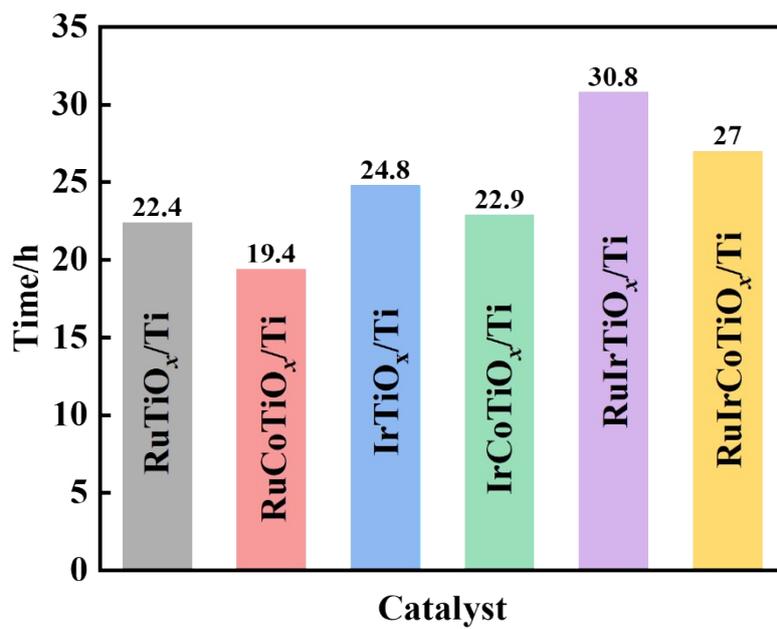


Fig. S6 The accelerated lifetime test performed in 1 M H₂SO₄ under 500 mA cm⁻² at 25°C.

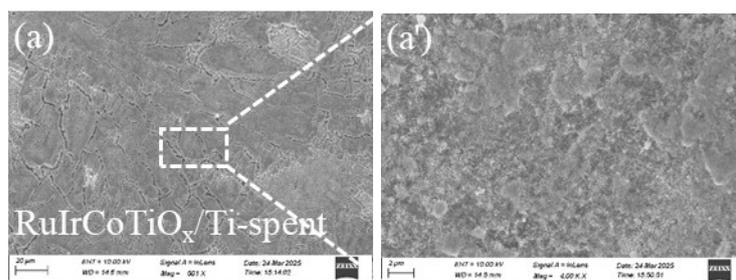


Fig. S7 The SEM images of RuIrCoTiO_x/Ti after accelerated lifetime experiment.

Table S3 Impedance parameters of Ru and Ir oxide anodes

	R_s	Q_l	n_l	R_l	Q_{dl}	n_{dl}	R_{ct}
	$/\Omega \cdot \text{cm}^2$	$/\text{F} \cdot \text{cm}^{-2}$		$/\Omega \cdot \text{cm}^2$	$/\text{F} \cdot \text{cm}^{-2}$		$/\Omega \cdot \text{cm}^2$
RuTiO _x /Ti	23.93	1.40×10^{-1}	0.70	67.66	1.26×10^{-3}	0.89	65.36
RuCoTiO _x /Ti	23.67	9.36×10^{-2}	0.59	96.02	1.33×10^{-3}	0.88	49.27
IrTiO _x /Ti	25.44	1.70×10^{-1}	0.88	50.75	9.29×10^{-4}	0.63	100.48
IrCoTiO _x /Ti	24.97	1.31×10^{-1}	0.64	90.37	1.02×10^{-3}	0.91	79.66
RuIrTiO _x /Ti	24.05	1.33×10^{-1}	0.64	107.38	1.48×10^{-3}	0.87	51.82
RuIrCoTiO _x /T	24.30	2.22×10^{-2}	0.67	39.16	9.19×10^{-2}	0.50	4.69

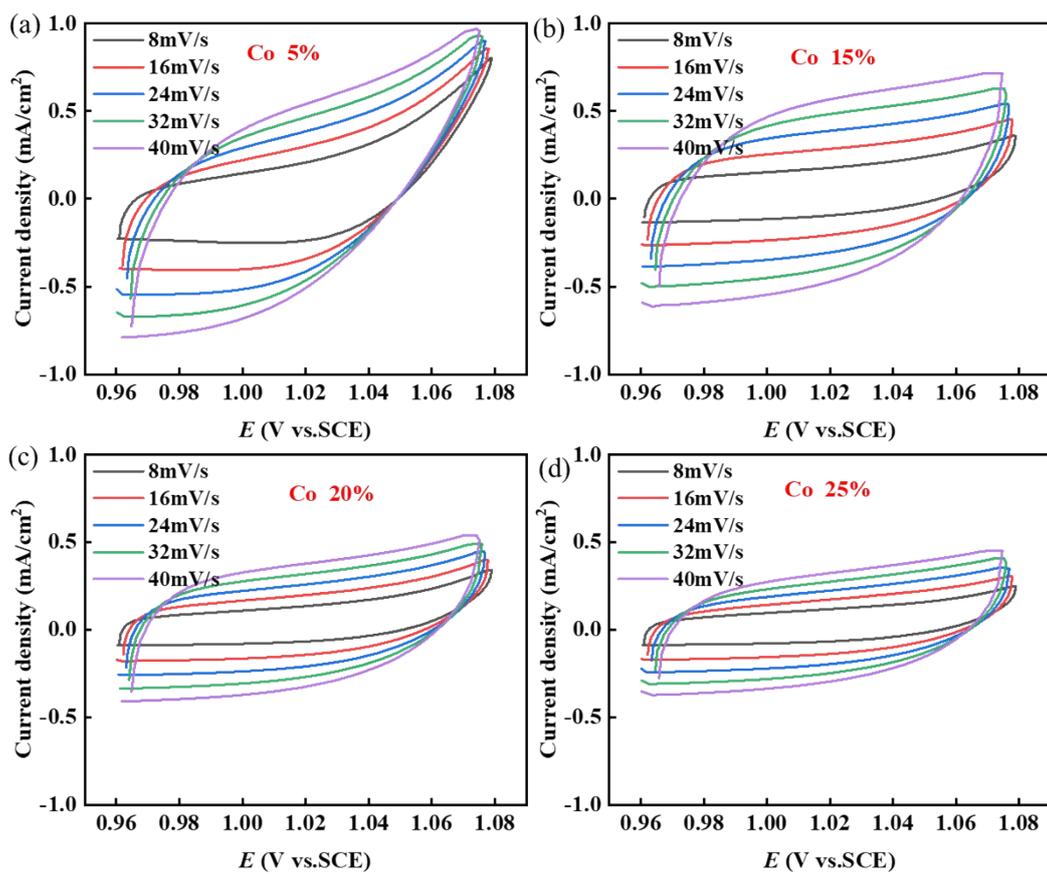


Fig. S8 CV curves of RuIrTiO_x/Ti with different Co addition amount in saturated NaCl solution at different scan rates ranging from 8 to 40 mV s⁻¹.

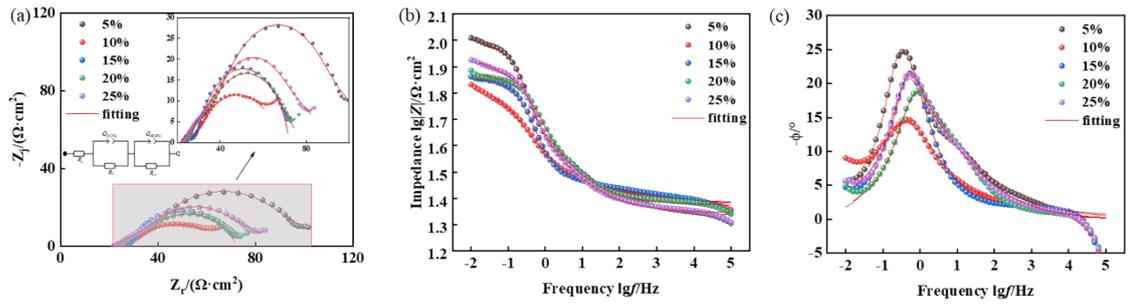


Fig. S9 The impedance diagrams of RuIrCoTiO_x/Ti with series content of Co. (a) Nyquist plots, inset: equivalent circuit model for EIS analysis; (b) Bode magnitude plot; (c) Bode phase angle plot.

Table S4 Impedance parameters of RuIrCoTiO_x/Ti with series content of Co

Co Content	R_s / $\Omega \cdot \text{cm}^2$	Q_1 / $\text{F} \cdot \text{cm}^{-2}$	n_1	R_t / $\Omega \cdot \text{cm}^2$	Q_{dl} / $\text{F} \cdot \text{cm}^{-2}$	n_{dl}	R_{ct} / $\Omega \cdot \text{cm}^2$
5%	21.43	2.46×10^{-2}	0.98	29.08	1.59×10^{-2}	0.39	67.87
15%	23.74	1.26×10^{-2}	0.85	44.42	1.45×10^{-2}	0.38	9.13
20%	23.73	1.70×10^{-2}	0.99	16.93	1.21×10^{-2}	0.51	37.05
25%	22.04	2.29×10^{-2}	0.86	16.08	1.43×10^{-2}	0.46	53.79

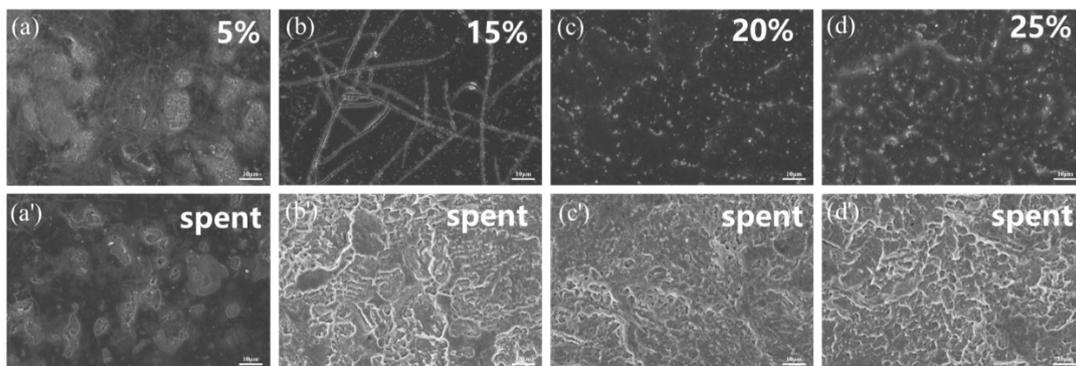


Fig. S10 The SEM images of RuIrCoTiO_x/Ti with series content of Co before and after accelerated lifetime experiment.