

Urchin-like hierarchical ruthenium cobalt oxide nanosheets on $\text{Ti}_3\text{C}_2\text{T}_x$ MXene as binder-free bifunctional electrode for overall water splitting and supercapacitors

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Fig. S1: Chronoamperometric data for electrodeposition of RuCo_2O_4 on $\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF electrode

Fig.S2: DFT simulation of $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2$ interface

Fig.S3: DFT-computed relative total energy of RuCo_2O_4

Fig.S4: EDS data of $\text{Ti}_3\text{C}_2\text{T}_x$ on NF electrode

Fig.S5: SEM, elemental mapping images and EDS of electrodeposited RuCo_2O_4 on $\text{Ti}_3\text{C}_2\text{T}_x$ @NF at 100 s

Fig.S6: SEM, elemental mapping images and EDS of electrodeposited RuCo_2O_4 on $\text{Ti}_3\text{C}_2\text{T}_x$ @NF at 500 s

Fig.S7: SEM and EDS analysis of RuCo_2O_4 @NF and SEM images of $\text{Co}_3\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, $\text{RuO}_2/\text{MXene@NF}$, Co_3O_4 @NF, RuO_2 @NF

Fig.S8: LSV curves of $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF electrode towards OER and HER at various deposition time of RuCo_2O_4

Fig.S9: CV curves of $\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, RuO_2 @NF, $\text{RuO}_2/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, RuCo_2O_4 @NF, Co_3O_4 @NF, $\text{Co}_3\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, and $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF at scan rate of 20 mV s^{-1}

Fig.S10: CV curves of $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF at various deposition time of RuCo_2O_4

Table S1: Fitting data of the Nyquist plots

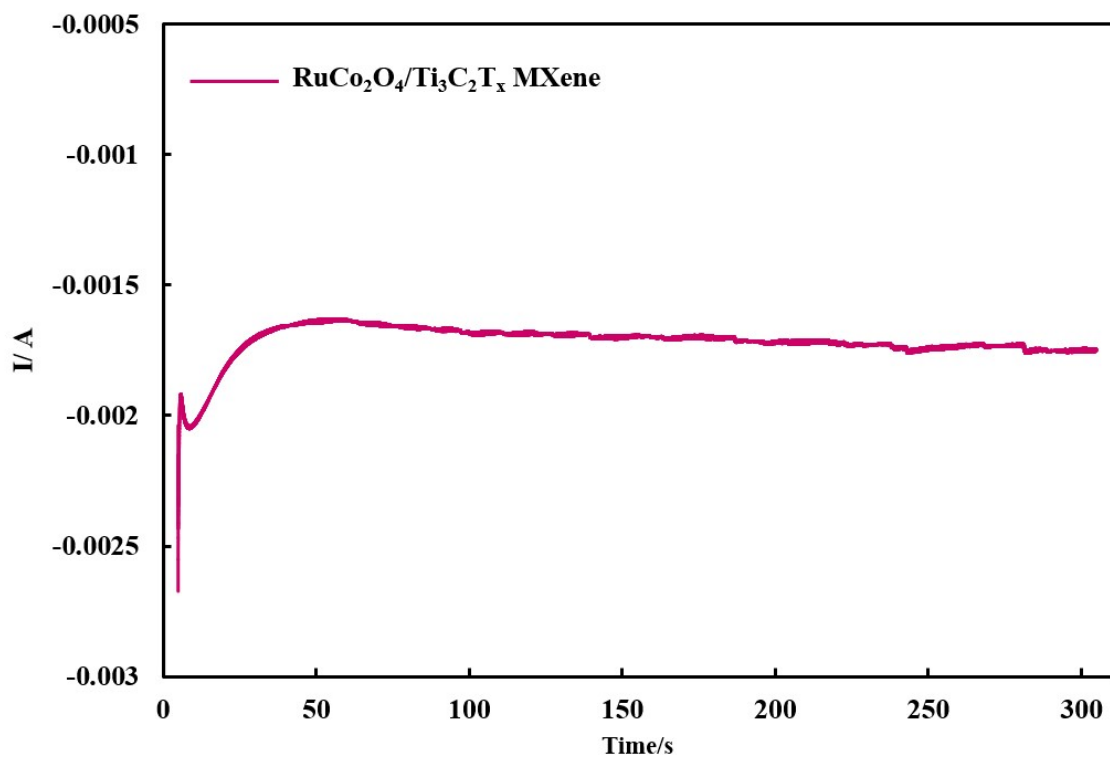


Fig.S1 I-t curve for electrodeposition of RuCo₂O₄ on Ti₃C₂T_x MXene@NF

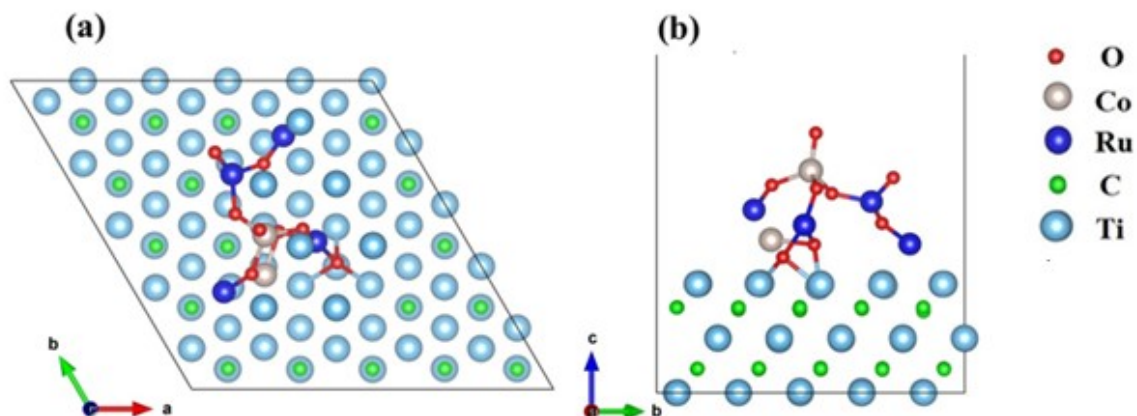


Fig. S2 DFT model of RuCo₂O₄/Ti₃C₂ interface: plane (a) and side (b) views of relaxed geometries of two-molecule RuCo₂O₄ cluster on a Ti₃C₂ (001) surface. Light blue, green, gray, dark blue and red balls represent Ti, C, Co, Ru and O atoms, respectively

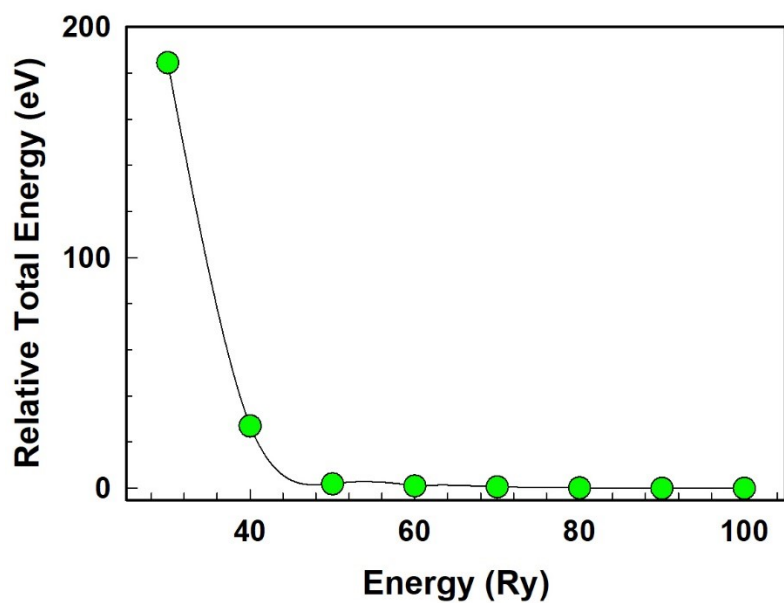


Fig. S3 Computed relative total energy of RuCo₂O₄ structure as a function of cut-off energy of expansion of electron wave function. The reference energy is the total energy of the structure for cut-off of 100 Ry.

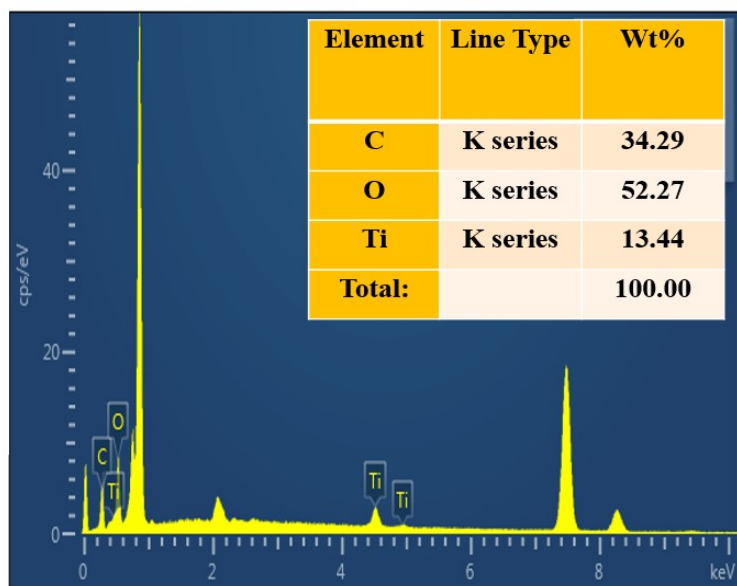


Fig.S4 EDS analysis of $Ti_3C_2T_x$ MXene@NF

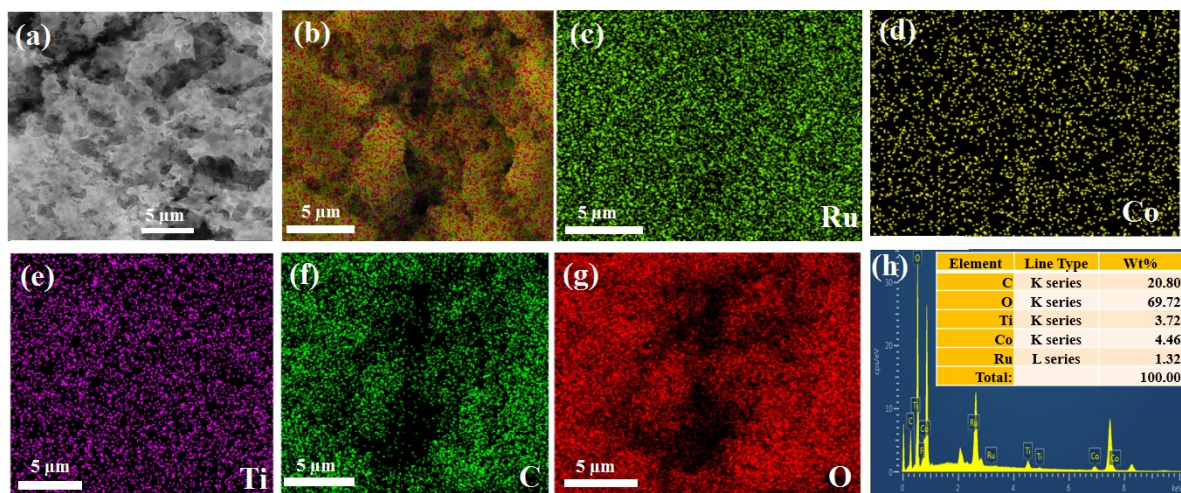


Fig.S5 (a) SEM image of $RuCo_2O_4/Ti_3C_2T_x$ MXene@NF at electrodeposition time of 100 s of $RuCo_2O_4$ on $Ti_3C_2T_x$ MXene@NF, and (b-h) SEM images and EDS analysis of the fabricated electrode

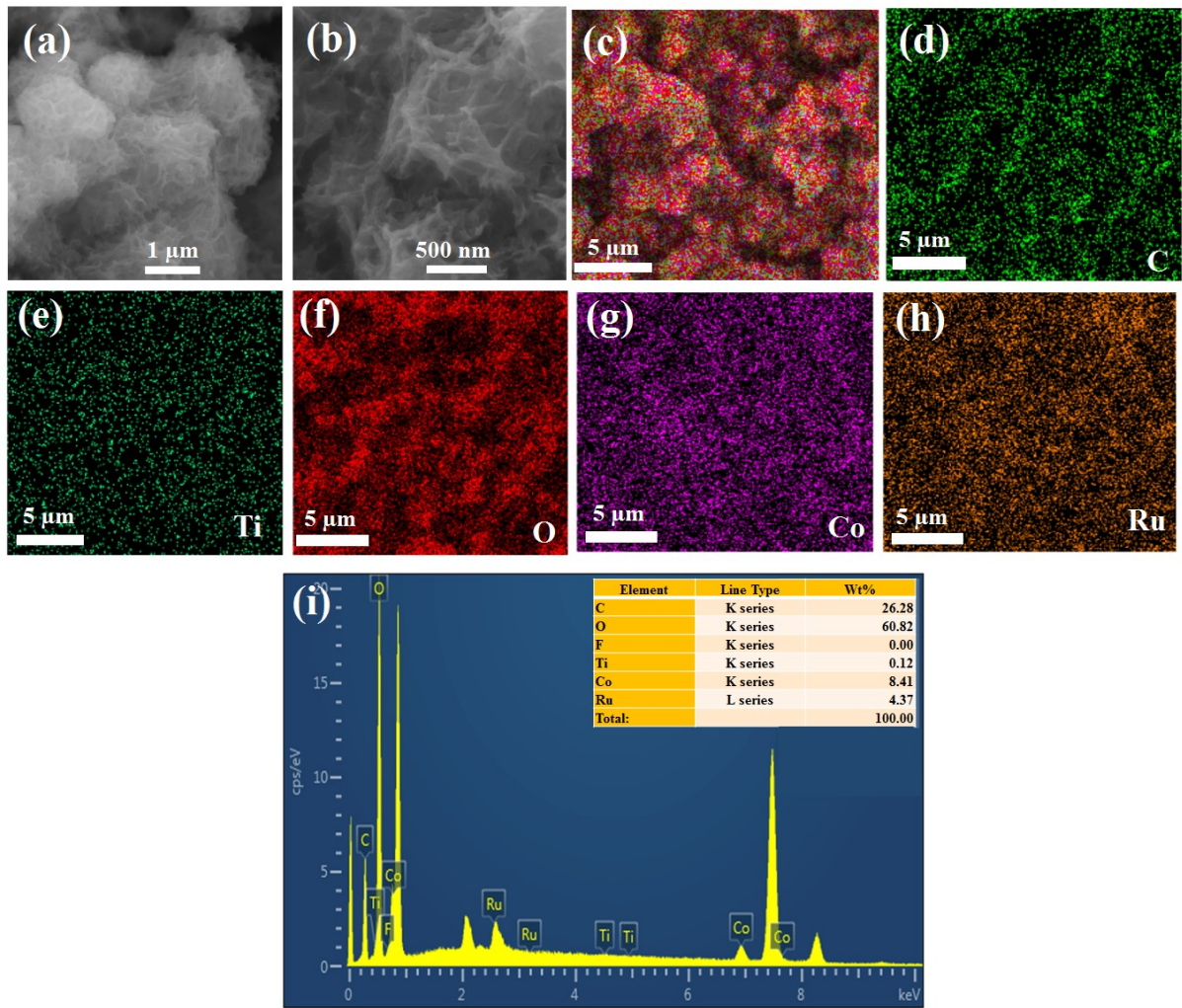


Fig.S6 (a, b) SEM image of $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene @NF at electrodeposition time of 500 s of RuCo_2O_4 on $\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, and (c-i) SEM images and EDS analysis of the fabricated electrode

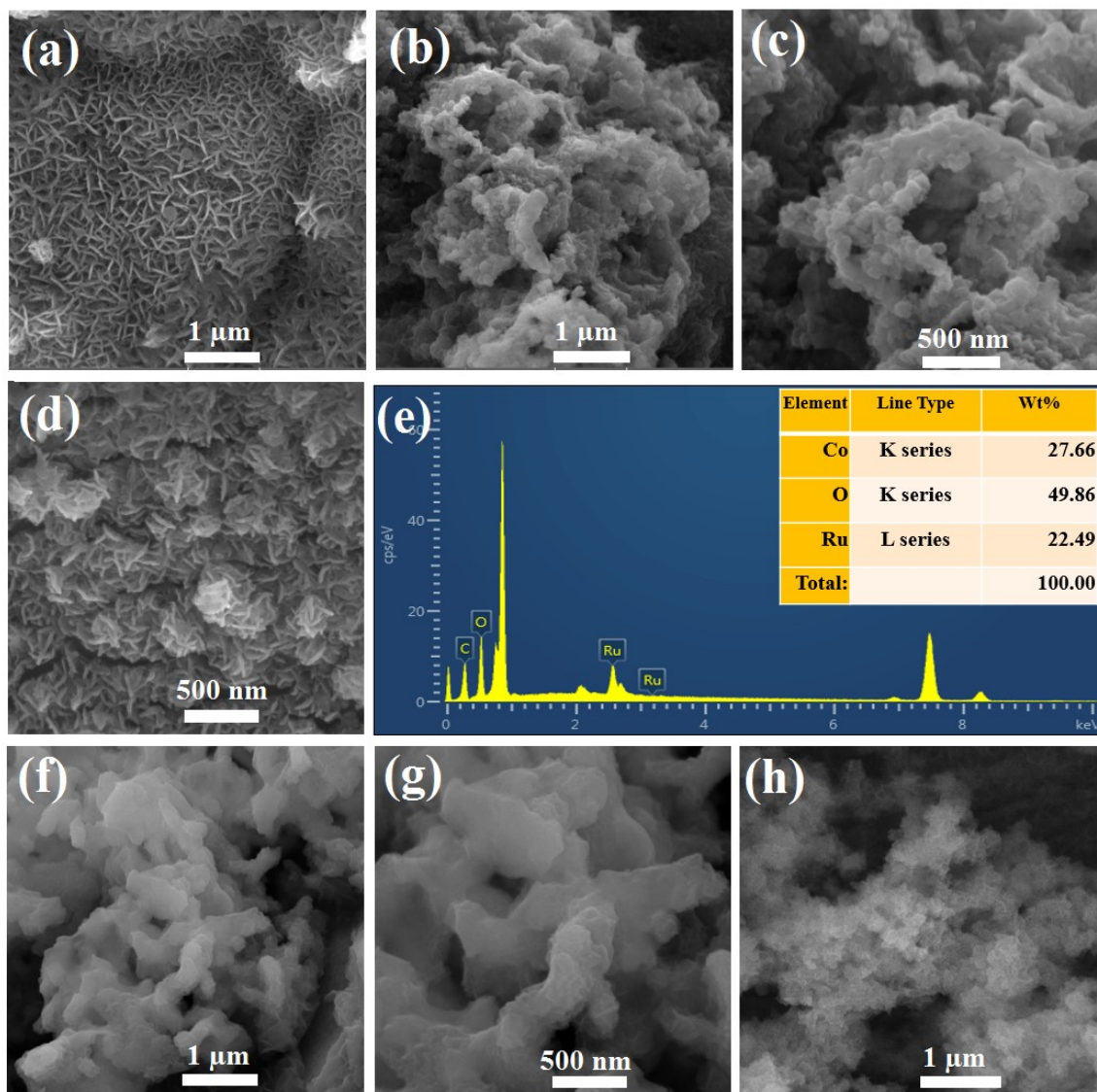


Fig.S7 SEM images of (a) $\text{Co}_3\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, (b,c) $\text{RuO}_2/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, (d), (e) SEM image and EDS analysis of RuCo_2O_4 @NF, (f, g) Co_3O_4 @NF and (h) RuO_2 @NF

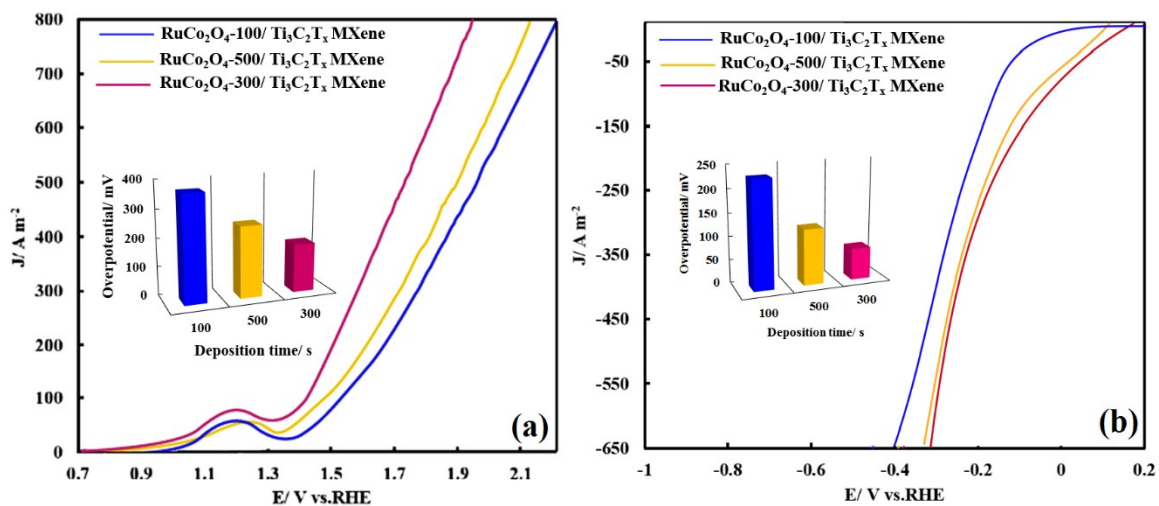


Fig.S8 (a) OER and (b) HER curves of RuCo₂O₄/Ti₃C₂T_x MXene @NF at different electrodeposition times of RuCo₂O₄ (100, 300 and 500 s) on the Ti₃C₂T_x MXene@NF electrode

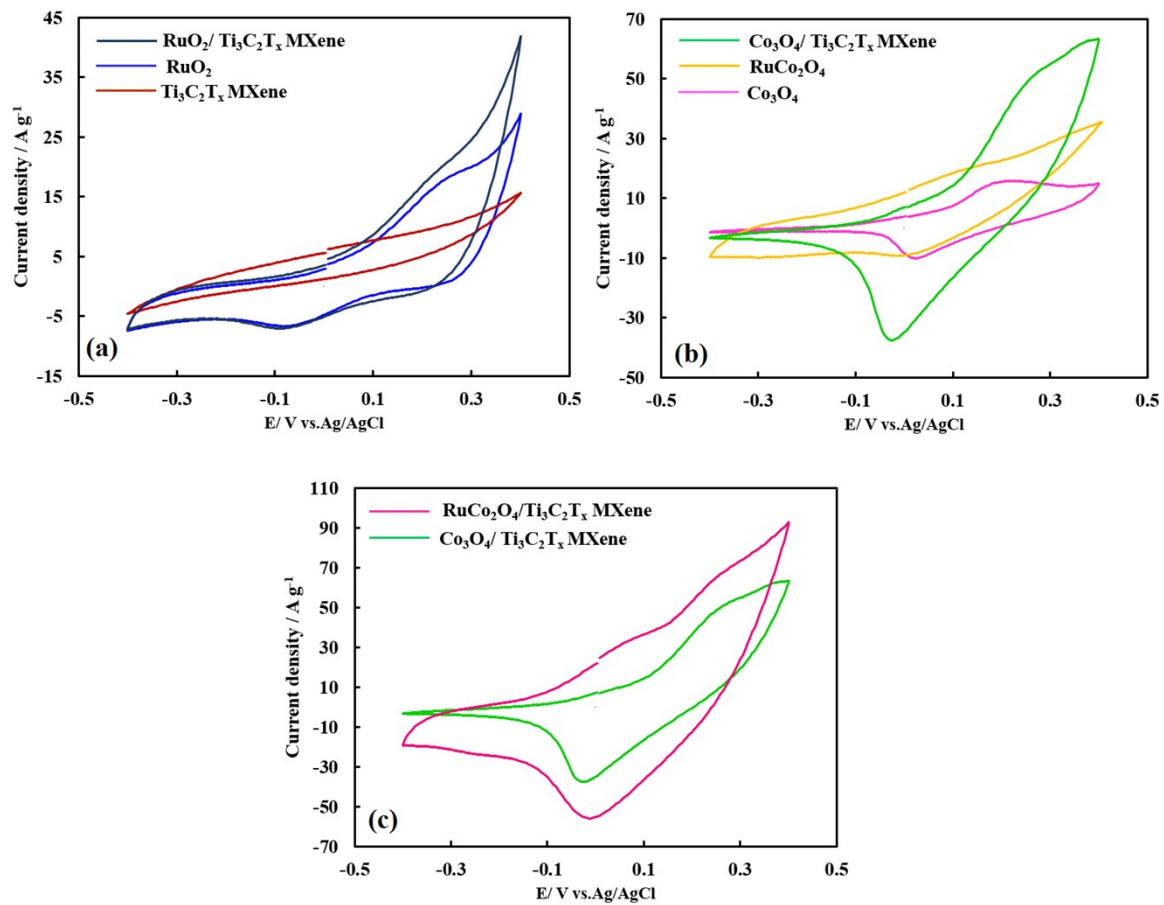


Fig.S9 CV curves of (a) $\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, RuO_2 @NF, $\text{RuO}_2/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, (b) RuCo_2O_4 @NF, Co_3O_4 @NF, $\text{Co}_3\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, (c) $\text{RuCo}_2\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF, $\text{Co}_3\text{O}_4/\text{Ti}_3\text{C}_2\text{T}_x$ MXene@NF

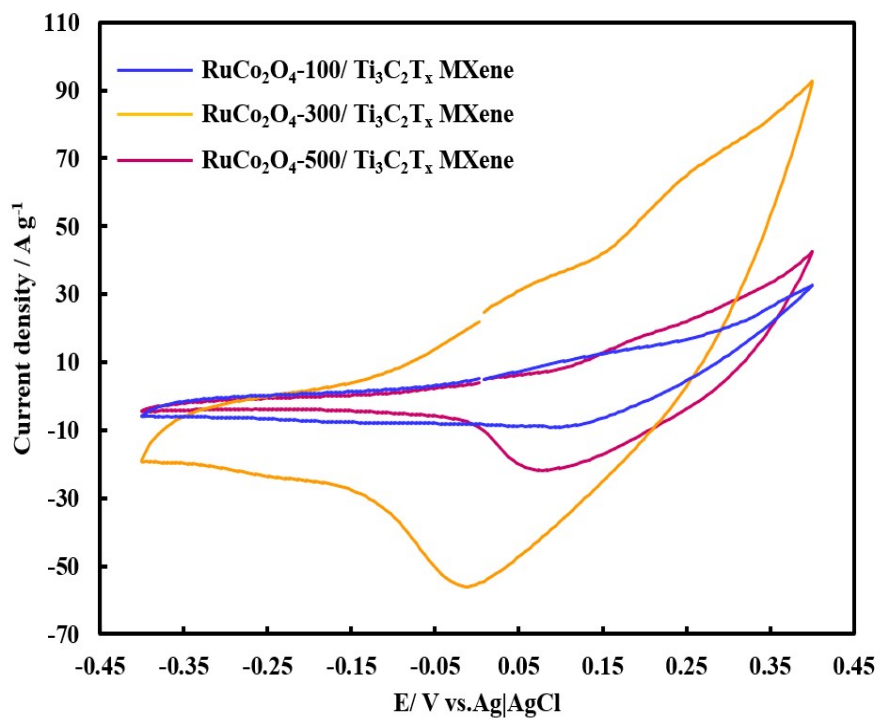


Fig.S10 CV curves of RuCo₂O₄/Ti₃C₂T_x MXene@NF at different electrodeposition times of RuCo₂O₄ (100, 300 and 500 s) on the Ti₃C₂T_x MXene@NF electrode surface at scan rate of 20 mV s⁻¹

Table S1 Fitting parameters used to simulate the EIS data obtained for prepared electrodes in alkaline media

Samples	R_s (Ω)	R₁ (Ω)	CPE1 ($\Omega^{-1}s$)	n1	W	n	CPE2 ($\Omega^{-1}s$)	n2
RuCo₂O₄/ Ti₃C₂T_x MXene@NF	0.005	1.2	2	0.95	0.06	0.4	1	0.4
RuO₂/ Ti₃C₂T_x MXene@NF	0.67	2	0.18	0.65	0.06	1	1.3	0.8
Co₃O₄/ Ti₃C₂T_x MXene@NF	0.005	4	0.6	0.8	0.02	0.39	0.4	0.7
RuCo₂O₄@NF	0.5	4	0.62	0.81	0.02	0.5	0.15	0.6
Co₃O₄@NF	1	8	0.61	0.83	0.02	0.35	0.6	0.8
RuO₂@NF	1	45	0.05	0.8	0.009	0.34	7	0.4
Ti₃C₂T_x MXene@NF	1	75	0.03	0.8	0.002	0.3	15	0.4