Urchin-like hierarchical ruthenium cobalt oxide nanosheets on $Ti_3C_2T_x$ MXene as binder-free bifunctional electrode for overall water splitting and supercapacitors

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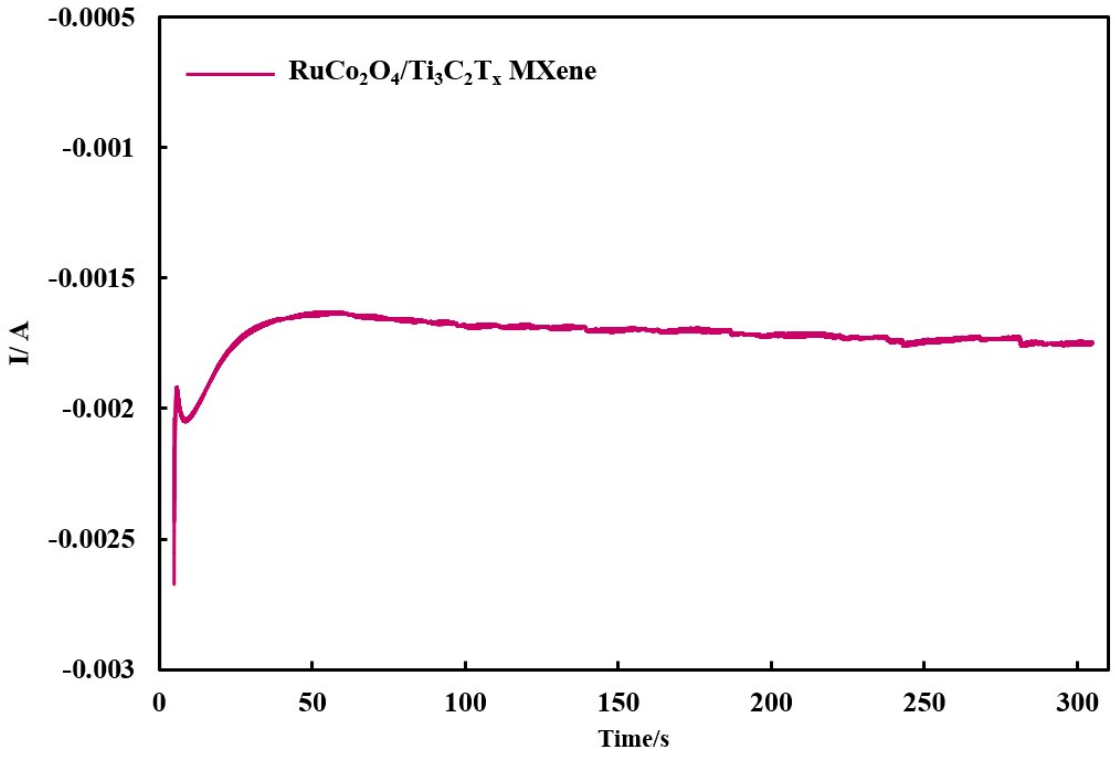

Fig.S1 I-t curve for electrodeposition of $RuCo_2O_4$ on $Ti_3C_2T_x$ MXene@NF

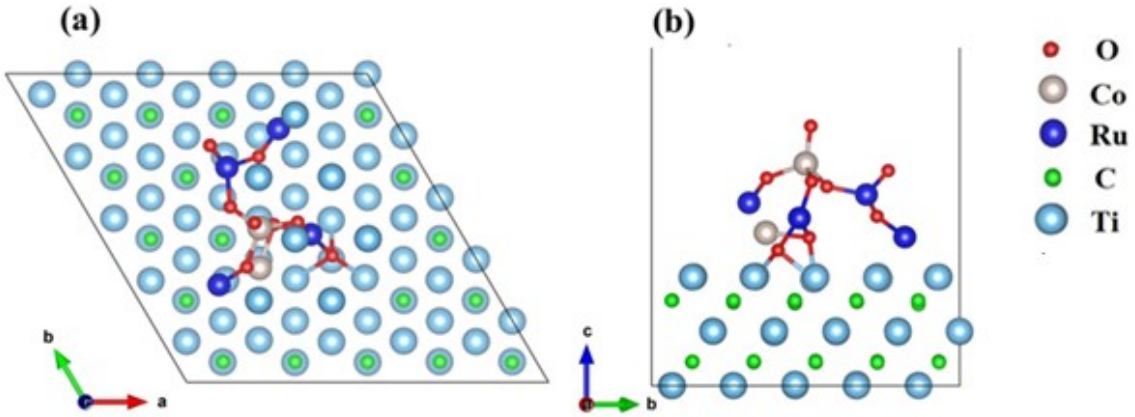

Fig. S2 DFT model of $RuCo_2O_4/Ti_3C_2$ interface: plane (a) and side (b) views of relaxed geometries of two-molecule $RuCo_2O_4$ cluster on a Ti_3C_2 (001) surface. Light blue, green, gray, dark blue and red balls represent Ti, C, Co, Ru and O atoms, respectively

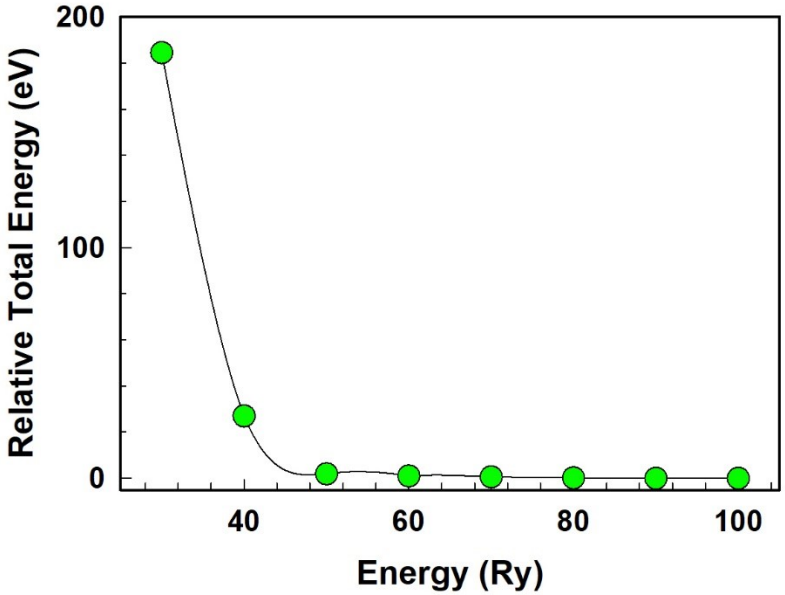

Fig. S3 Computed relative total energy of $RuCo_2O_4$ structure as a function of cut-off energy of expansion of electron wave function. The reference energy is the total energy of the structure for cut-off of 100 Ry.

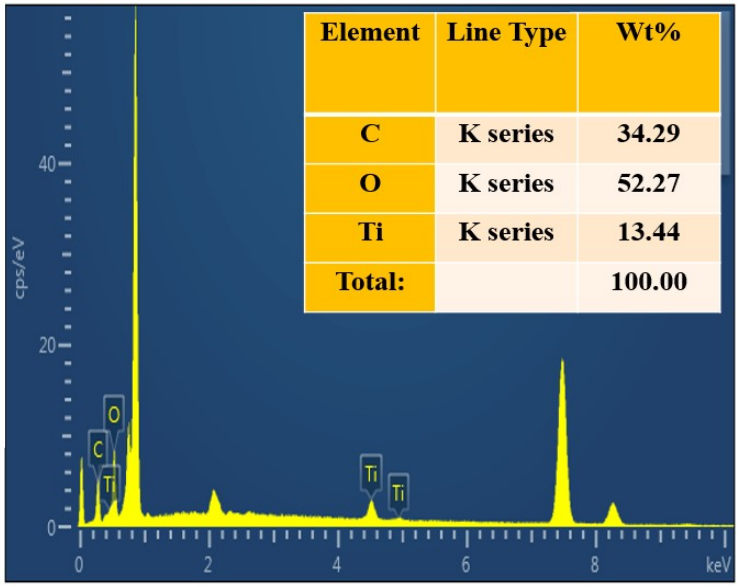

Fig.S4 EDS analysis of $Ti_3C_2T_x$ MXene@NF

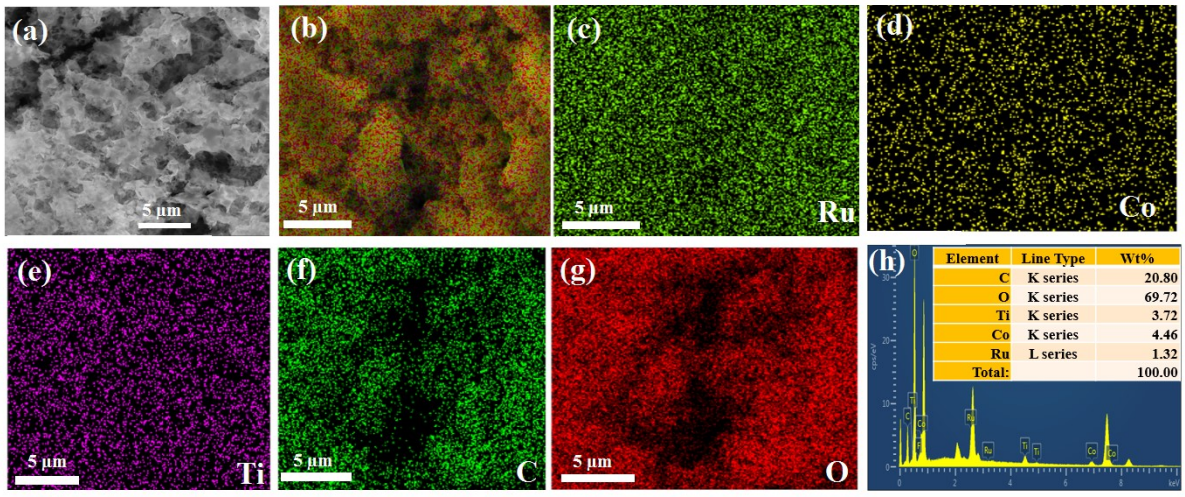

Fig.S5 (a) SEM image of $RuCo_2O_4/Ti_3C_2T_x$ MXene@NF at electrodeposition time of 100 s of $RuCo_2O_4$ on $Ti_3C_2T_x$ MXene@NF, and (b-h) SEM images and EDS analysis of the fabricated electrode

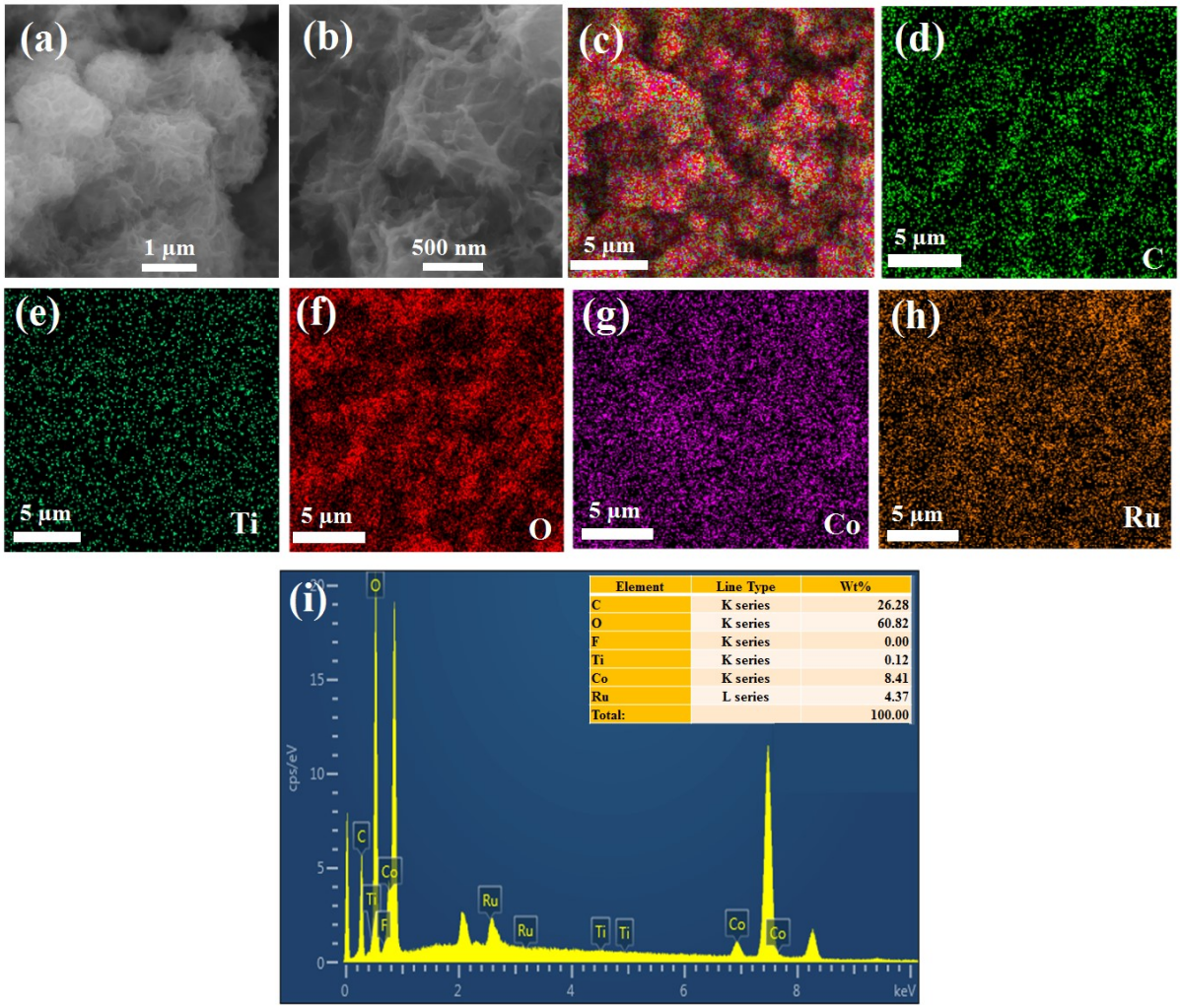

Fig.S6 (a, b) SEM image of $RuCo_2O_4/Ti_3C_2T_x$ MXene @NF at electrodeposition time of 500 s of $RuCo_2O_4$ on $Ti_3C_2T_x$ MXene@NF, and (c-i) SEM images and EDS analysis of the fabricated electrode

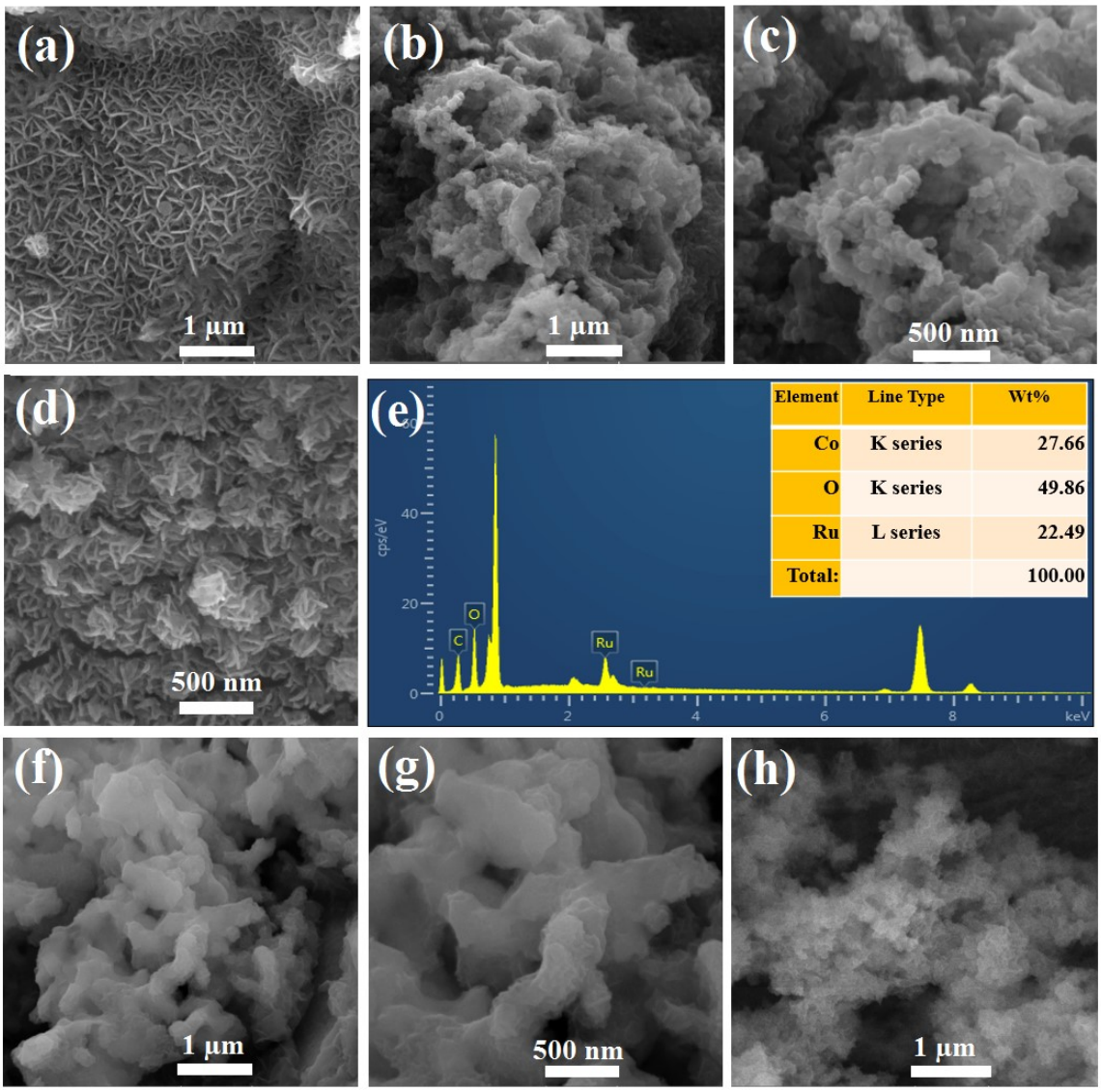

Fig.S7 SEM images of (a) $Co_3O_4/Ti_3C_2T_x$ MXene@NF, (b,c) $RuO_2/Ti_3C_2T_x$ MXene@NF, (d ,e) SEM image and EDS analysis of $RuCo_2O_4$@NF, (f, g) Co_3O_4@NF and (h) RuO_2@NF

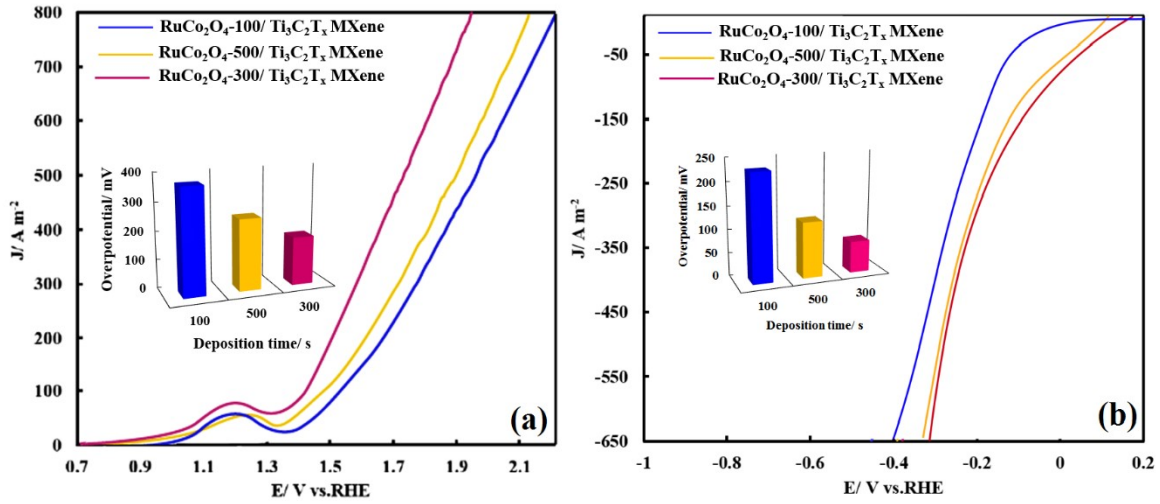

Fig.S8 (a) OER and (b) HER curves of $RuCo_2O_4/Ti_3C_2T_x$ MXene @NF at different electrodeposition times of $RuCo_2O_4$ (100, 300 and 500 s) on the $Ti_3C_2T_x$ MXene@NF electrode

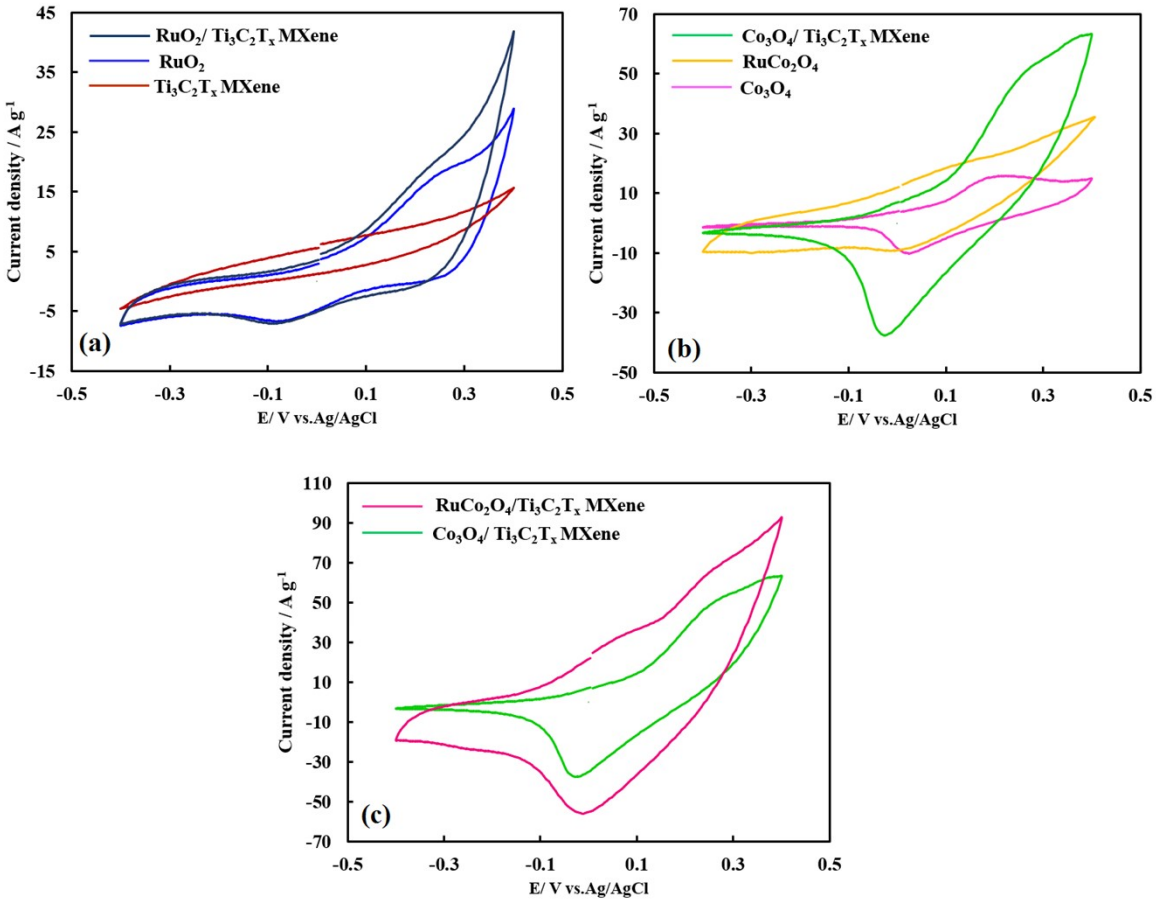

Fig.S9 CV curves of (a) $Ti_3C_2T_x$ MXene@NF, RuO_2@NF, RuO_2/ $Ti_3C_2T_x$ MXene@NF, (b) $RuCo_2O_4$@NF, Co_3O_4@NF, Co_3O_4/ $Ti_3C_2T_x$ MXene@NF, (c) $RuCo_2O_4$/ $Ti_3C_2T_x$ MXene@NF, Co_3O_4/ $Ti_3C_2T_x$ MXene@NF

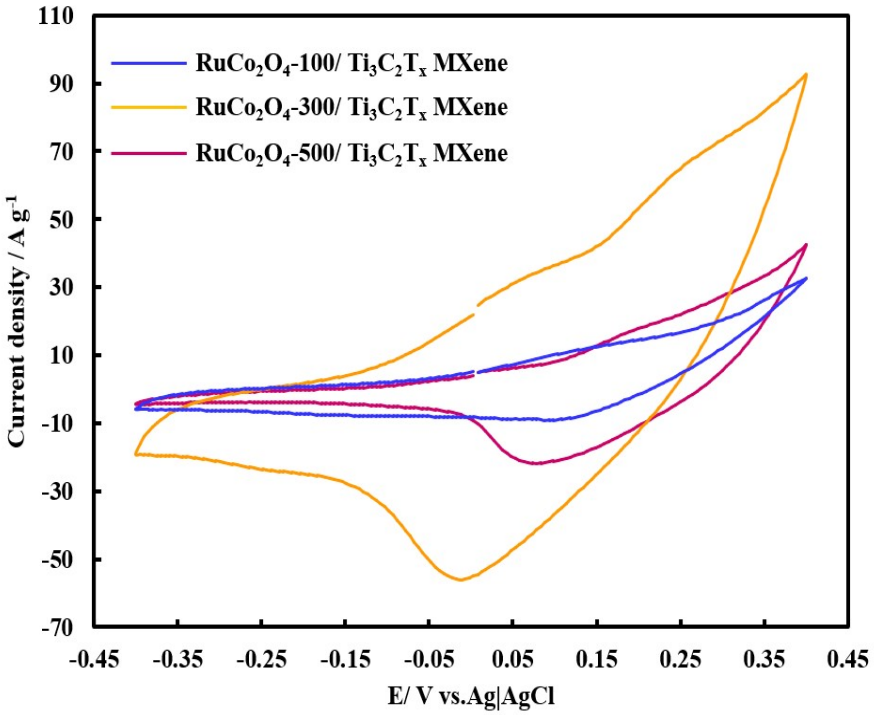

Fig.S10 CV curves of $RuCo_2O_4/Ti_3C_2T_x$ MXene@NF at different electrodeposition times of $RuCo_2O_4$ (100, 300 and 500 s) on the $Ti_3C_2T_x$ MXene@NF electrode surface at scan rate of 20 mV s^{-1}

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

Samples	R_s (Ω)	R_1 (Ω)	CPE1 ($\Omega^{-1}s$)	n1	W	n	CPE2 ($\Omega^{-1}s$)	n2
$RuCo_2O_4$/ $Ti_3C_2T_x$ MXene@NF	0.005	1.2	2	0.95	0.06	0.4	1	0.4
RuO_2/ $Ti_3C_2T_x$ MXene@NF	0.67	2	0.18	0.65	0.06	1	1.3	0.8
Co_3O_4/ $Ti_3C_2T_x$ MXene@NF	0.005	4	0.6	0.8	0.02	0.39	0.4	0.7
$RuCo_2O_4$@NF	0.5	4	0.62	0.81	0.02	0.5	0.15	0.6
Co_3O_4@NF	1	8	0.61	0.83	0.02	0.35	0.6	0.8
RuO_2@NF	1	45	0.05	0.8	0.009	0.34	7	0.4
$Ti_3C_2T_x$ MXene@NF	1	75	0.03	0.8	0.002	0.3	15	0.4