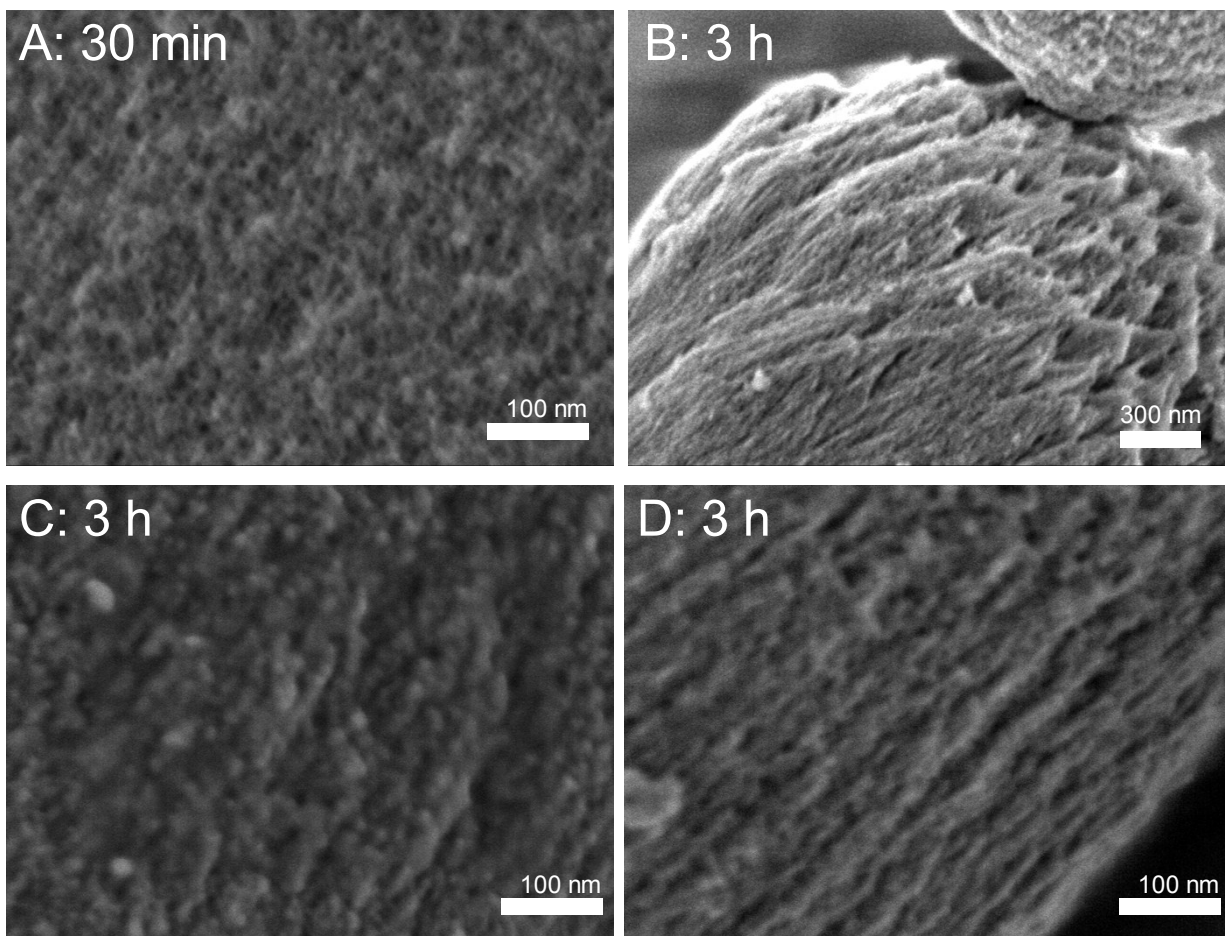


## Supporting information

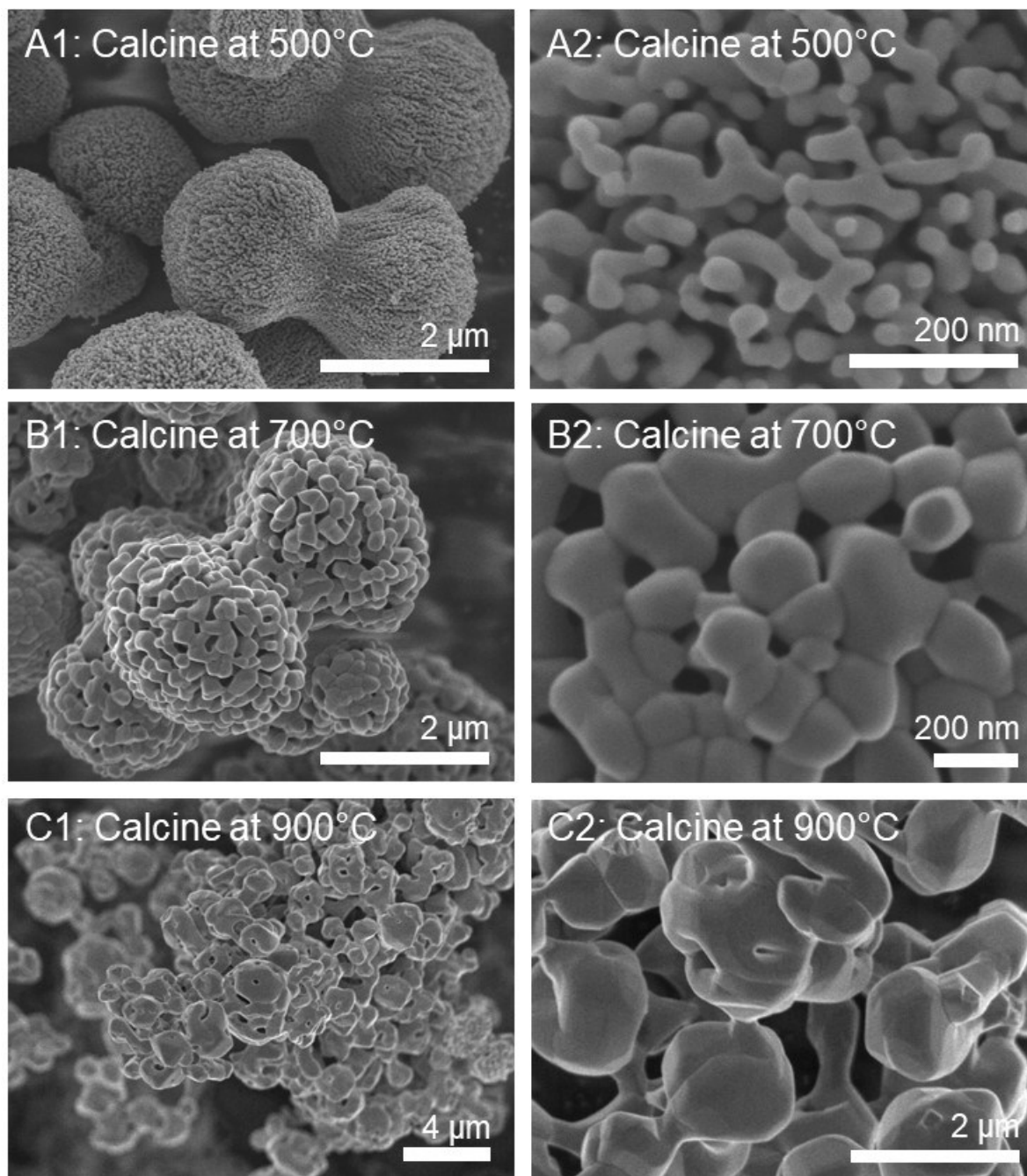
### **Bifunctional electrocatalytic CoNi-doped manganese oxide produced from microdumbbell manganese carbonate towards oxygen reduction and oxygen evolution reactions**

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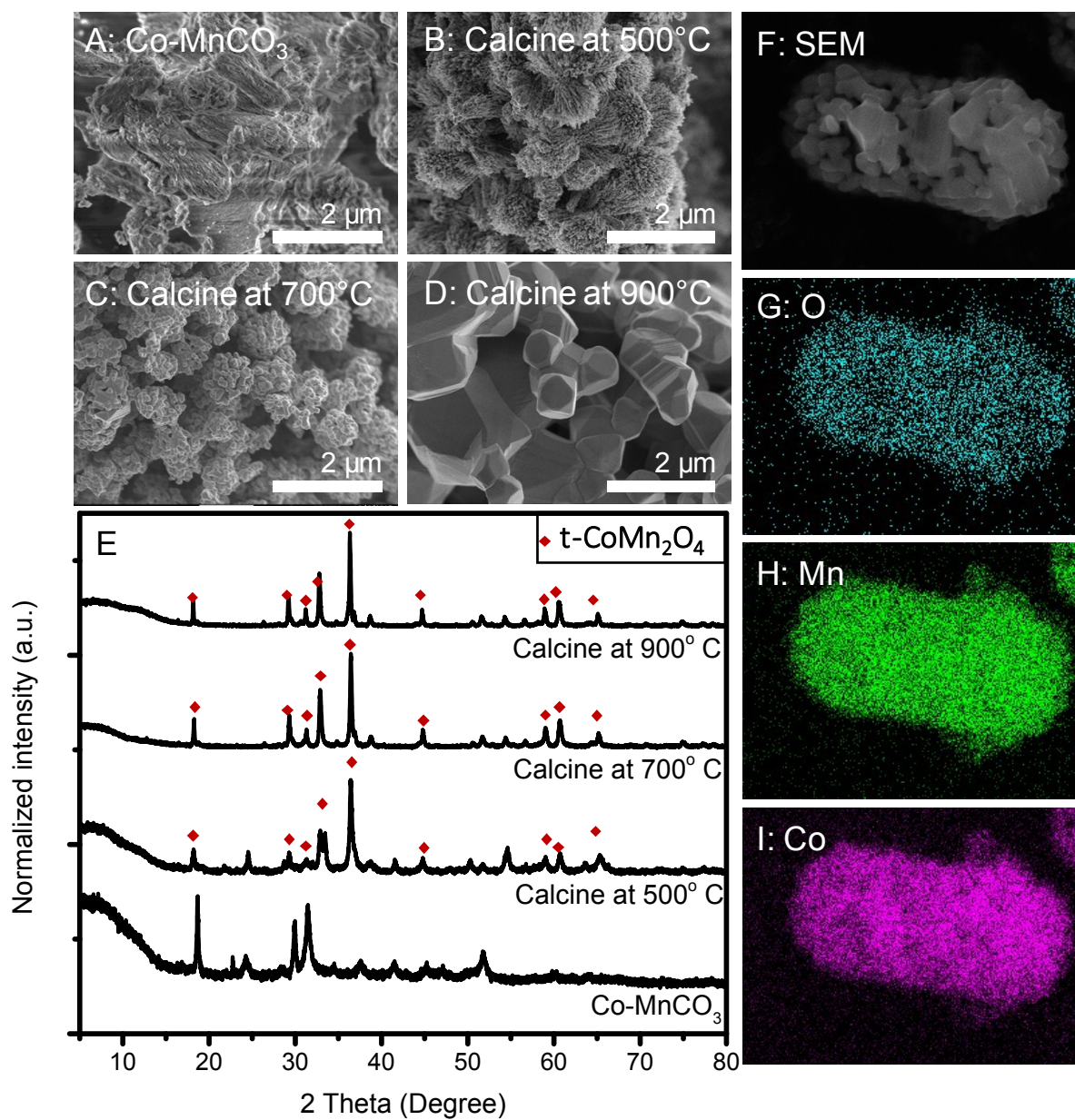
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Rayong 21210, Thailand



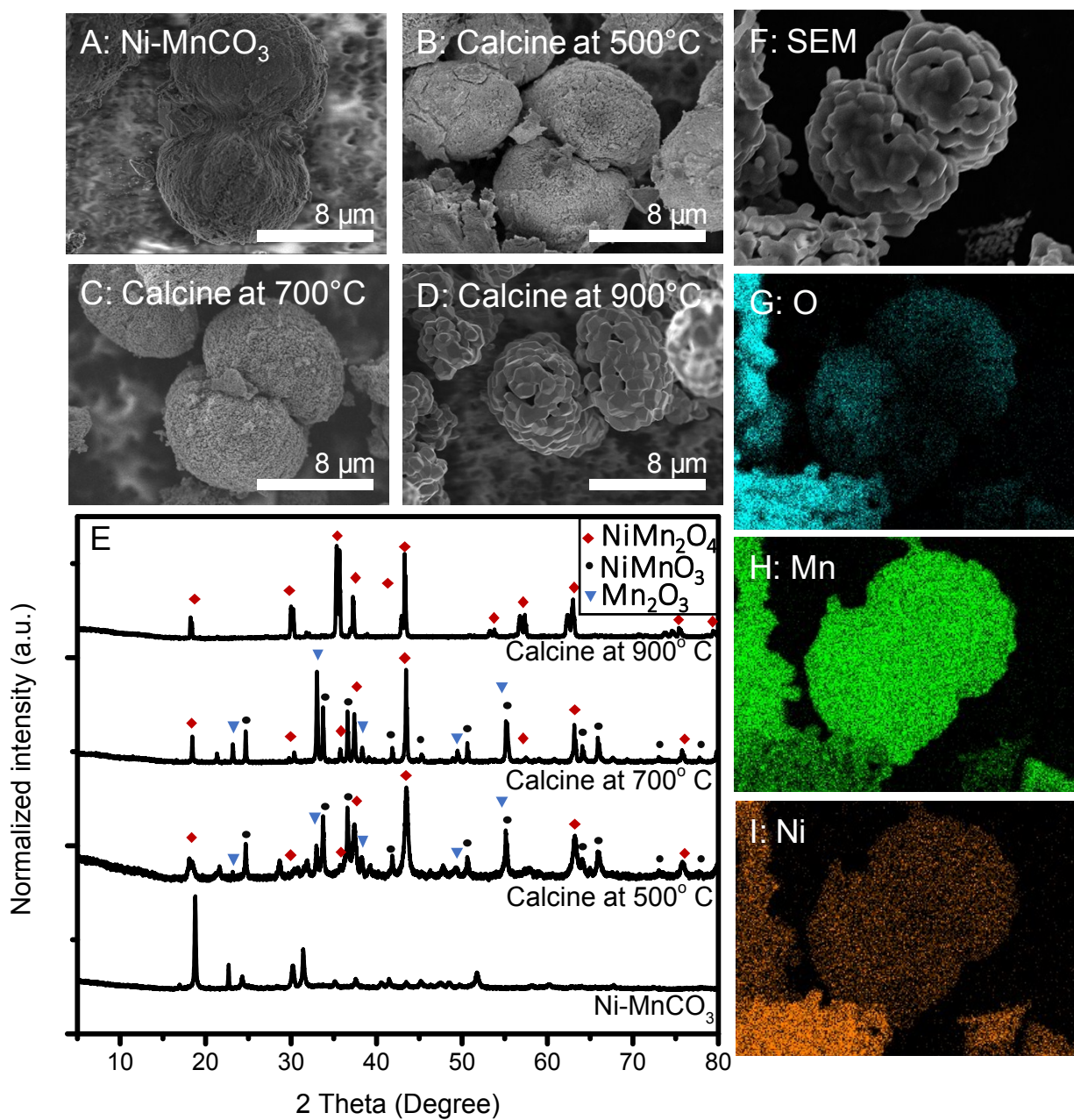
**Fig. S1.** Evidences of oriented attachment mechanism. (A)  $\text{MnCO}_3$  nanospheres were developed at the early stage of formation (30 min). (C) – (D) The chain-like structures were formed by an assembly of  $\text{MnCO}_3$  nanospheres (3 h).



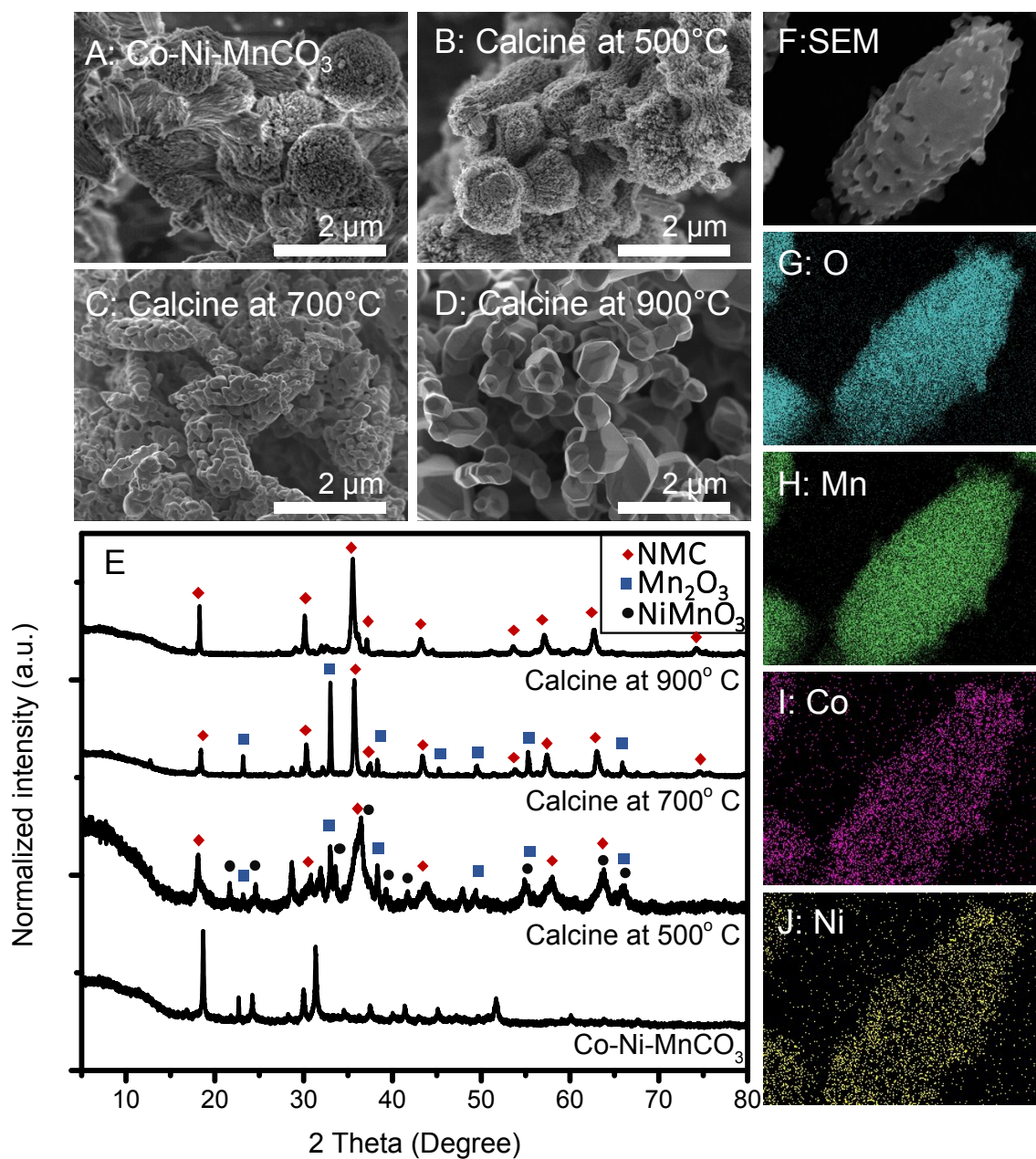
**Fig. S2.** Low and high magnification SEM images of the manganese oxides after calcination at (A) 500°C, (B) 700°C and (C) 900°C.



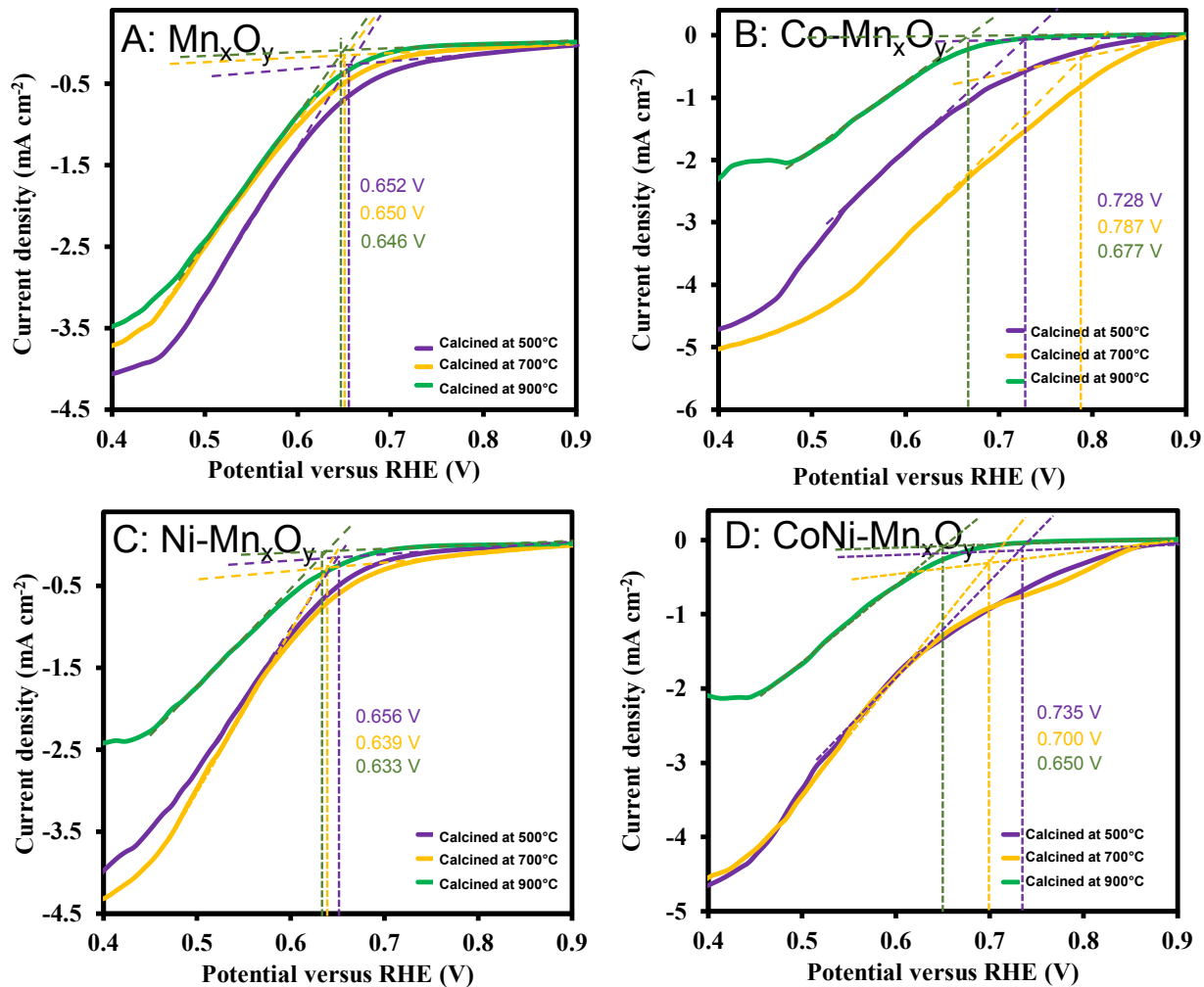
**Fig. S3.** SEM images of  $\text{Co-MnCO}_3$  (A) before and after calcination at (B) 500°C, (C) 700°C and (D) 900°C. (E) XRD patterns of samples corresponding to those of SEM images. (F) SEM image and corresponding elemental maps representing the distribution of (G) O, (H) Mn, and (I) Co from the product calcined at 700°C.



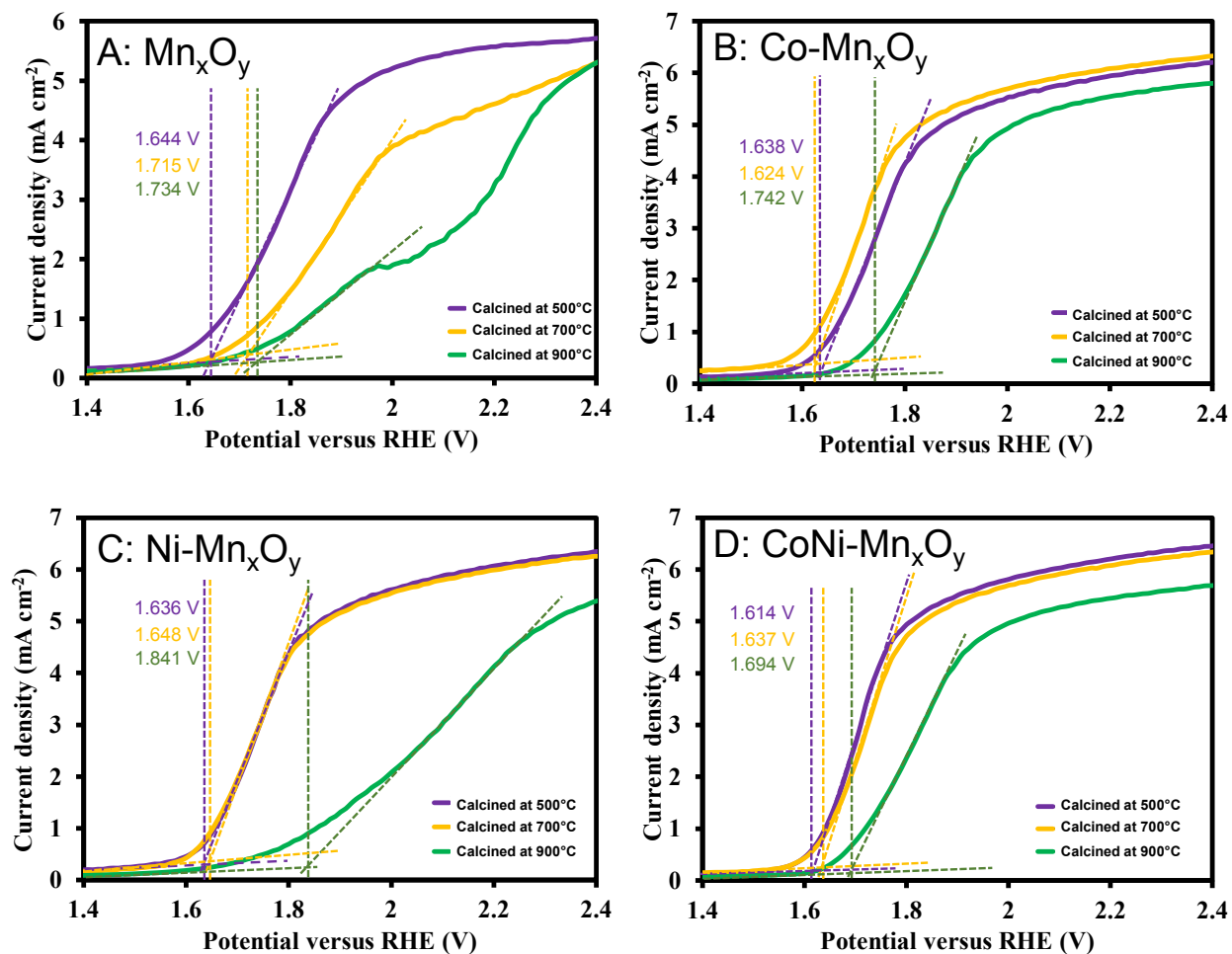
**Fig. S4.** SEM images of Ni-MnCO<sub>3</sub> (A) before and after calcination at (B) 500°C, (C) 700°C and (D) 900°C. (E) XRD patterns of samples corresponding to those of SEM images. (F) SEM image and corresponding elemental maps representing the distribution of (G) O, (H) Mn, and (I) Ni from the product calcined at 900°C.



**Fig. S5.** SEM images of CoNi-MnCO<sub>3</sub> (A) before and after calcination at (B) 500°C, (C) 700°C and (D) 900°C. (E) XRD patterns of samples corresponding to those of SEM images. (F) SEM image and corresponding elemental maps representing the distribution of (G) O, (H) Mn, (I) Co and (J) Ni from the product calcined at 700°C.



**Fig. S6.** Electrochemical performances measured by a linear sweep voltammetry at a scan rate of  $10 \text{ mV s}^{-1}$  of metal oxide catalysts calcined with different temperatures for the ORR: (A) manganese oxide, (B) Co-doped manganese oxide, (C) Ni-doped manganese oxide and (D) CoNi-doped manganese oxide.



**Fig. S7.** Electrochemical performances measured by a linear sweep voltammetry at a scan rate of  $10 \text{ mV s}^{-1}$  of metal oxide catalysts calcined with different temperatures for the OER: (A) manganese oxide, (B) Co-doped manganese oxide, (C) Ni-doped manganese oxide and (D) CoNi-doped manganese oxide.