Supporting Information

Improving the oxygen evolution performance of iron–manganese oxyhydroxides by Cr doping

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Synthesis of $FeMnCr_{0.6}OOH/NF$

$FeMnCr_{0.6}OOH/NF$ was synthesized using hydrothermal synthesis method. 0.2703 g $FeCl_3·6H_2O$, 0.1979 g $MnCl_2·4H_2O$, 0.1599 g $CrCl_3$, 0.24 g NH_2CONH_2 and 0.075 g PVP were dissolved in 15 mL H_2O via ultrasonic treatment. Subsequently, the solution was transferred into a 20 mL Teflon autoclave and a piece of clear NF was added, which was heated at 100 °C for 12 hours. Finally, the resulted NF was washed three times with ethanol and distilled water and dried at 60 °C for 12 hours, which was nominated as $FeMnCr_{0.6}OOH/NF$. For comparison, $FeMnCr_nOOH/NF$ (n = 0.4, 0.6, 0.8 and 1.0), FeOOH/NF, MnOOH/NF, CrOOH/NF, FeMnOOH/NF, $MnCr_{0.6}OOH/NF$, $FeCr_{0.6}OOH/NF$, FeMnNiOOH/NF, FeMnCoOOH/NF, FeMnCuOOH/NF, FeMnZnOOH/NF, and FeMnScOOH/NF samples were

synthesized by a similar method. $FeMnCr_{0.6}O_x$/NF was prepared by calcining $FeMnCr_{0.6}OOH$/NF in air at 500 °C for 2 h.

Characterization

Powder X-ray diffraction (XRD) patterns were collected by a Rigaku D/MAX-2600 scanning. Transmission electron microscope (TEM) images were observed by a FEI Tecnai F20. High-resolution TEM (HRTEM) images were recorded on a JEM-2100 transmission electron microscope at 200 kV. Scanning electron microscopy (SEM) images were recorded on a ZEISS GeminiSEM 300 field emission scanning electron microscope. X-ray photoelectron spectroscopy (XPS) was recorded on a Thermo Fisher Scientific Nexsa G2.

Electrochemical measurements

All electrochemical measurements were performed on a CHI760E electrochemical working station using a typical three-electrode configuration in 1 M KOH aqueous solution. Linear sweep voltammetry (LSV) polarization curves were acquired at a scan rate of 5 $mV \cdot s^{-1}$. Electrochemical impedance spectroscopy (EIS) measurements were performed at open-circuit potential in the frequency range from 100 kHz to 0.1 Hz with an a.c. perturbation of 5 mV. All potentials measured were calibrated to RHE using the following equation: E (versus RHE) = E (versus SCE) + 0.241 V + 0.0591 pH.

The Faradaic efficiency was calculated using the equations:

$$FE = (V/V_m)\, e\, N_A\, Z/Q$$

where V is the volume of gas (L), V_m is the standard molar volume (22.4 L mol^{-1}), e is the electron charge, NA is the Avogadro number (6.02×10^{23}), Z is the number of electrons needed to form O_2 molecular (for O_2, Z = 4), and Q is the amount of power consumed during electrolysis (C)

The TOF value was calculated using the equations:

$$TOF = J_A\, A/(4 \cdot n \cdot F)$$

where J_A is the current density at 95% iR-corrected overpotential = 300 mV, A is the area of the working electrode (cm^2), n is the amount of substance at the active site (mol), F is the Faraday constant.

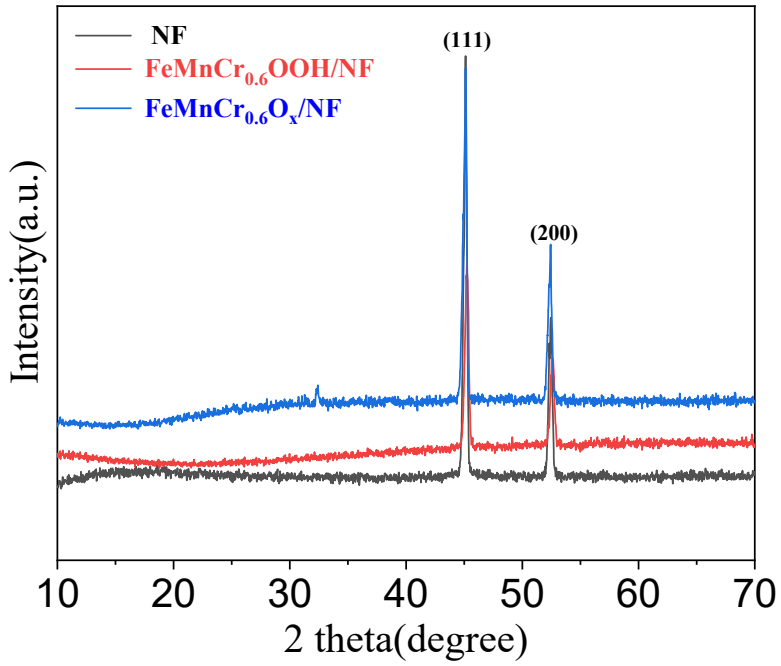

Fig. S1. XRD patterns of NF, $FeMnCr_{0.6}OOH$/NF and $FeMnCr_{0.6}O_x$/NF.

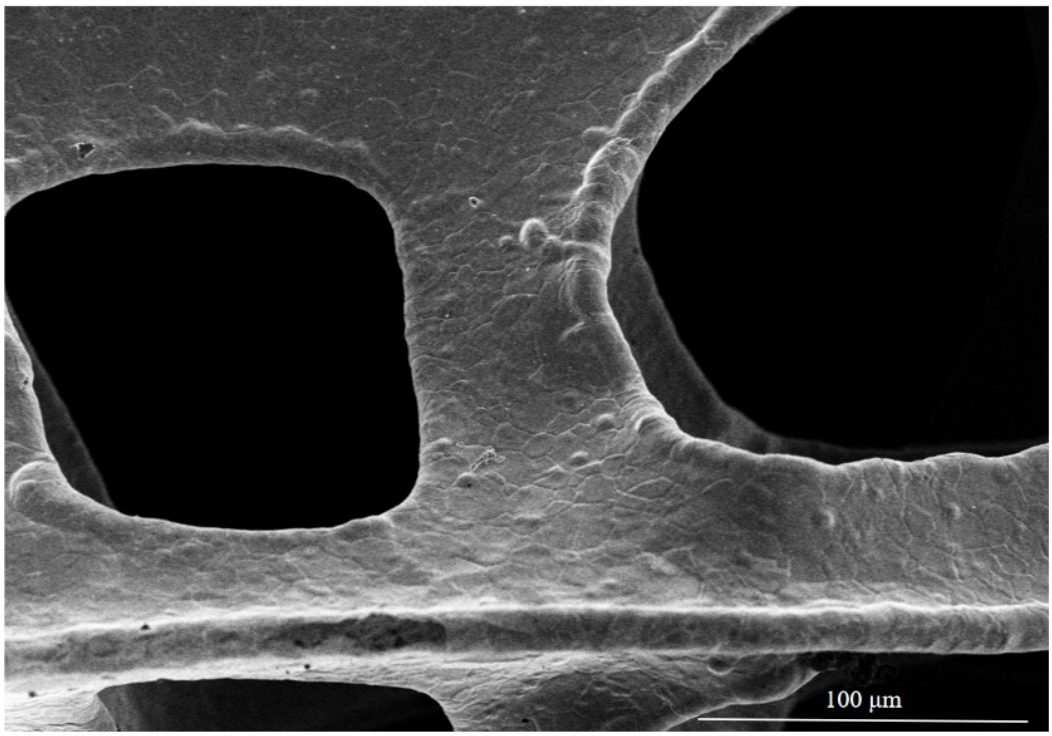

Fig. S2. SEM image of NF.

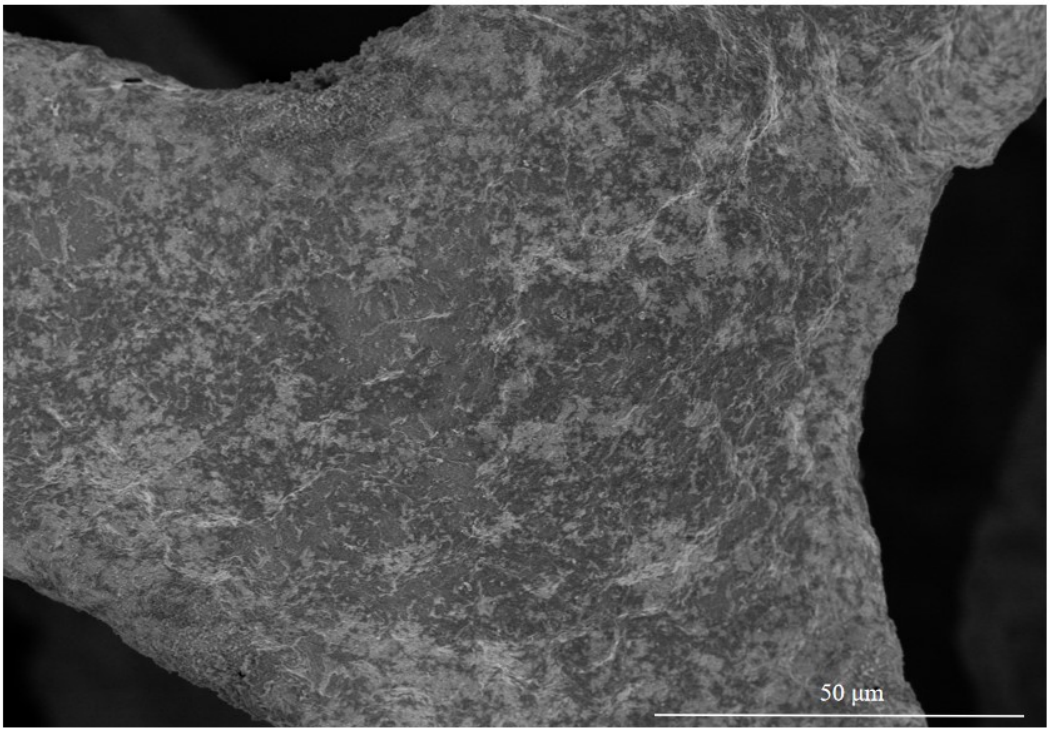

Fig. S3. SEM image of $FeMnCr_{0.6}OOH$/NF.

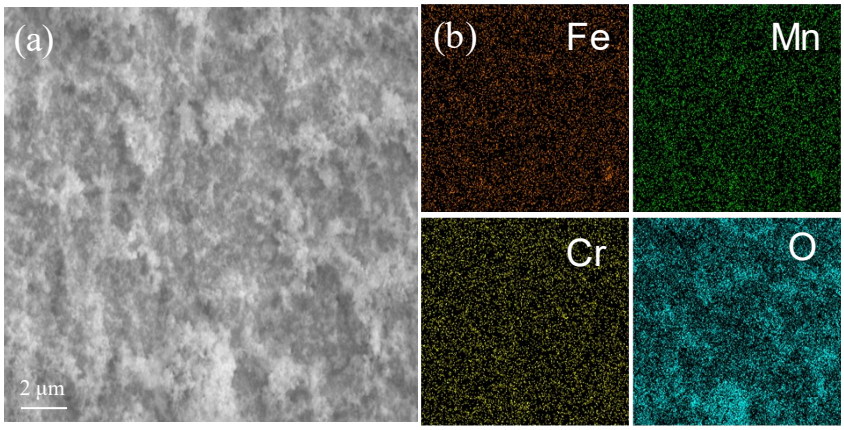

Fig. S4. (a) SEM image and (b) element mapping of $FeMnCr_{0.6}OOH$/NF.

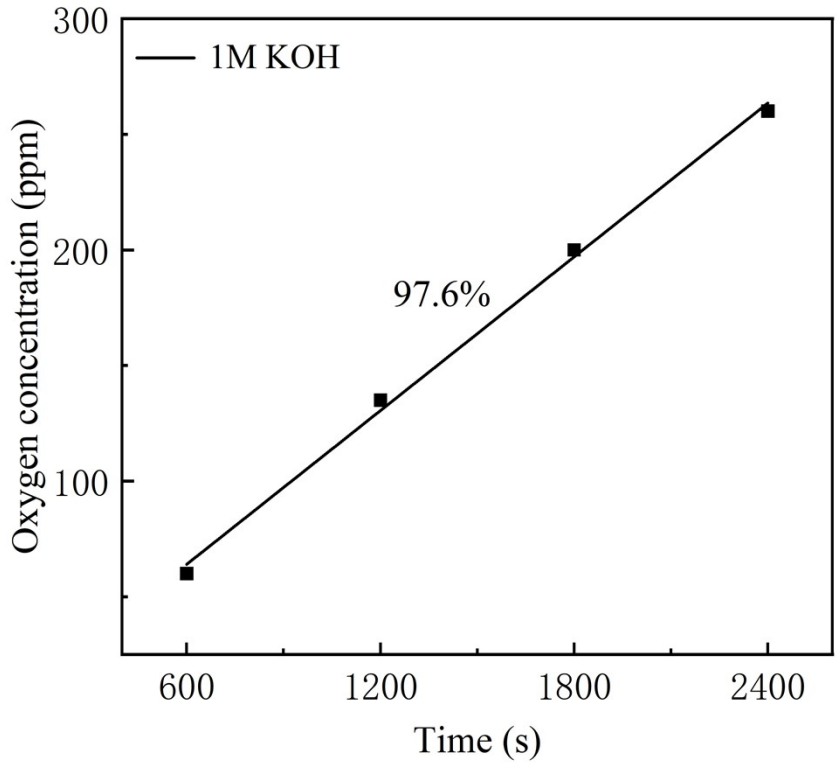

Fig. S5. Faraday efficiency of FeMnCr0.6OOH/NF in 1M KOH at 10 mA cm^{-2}.

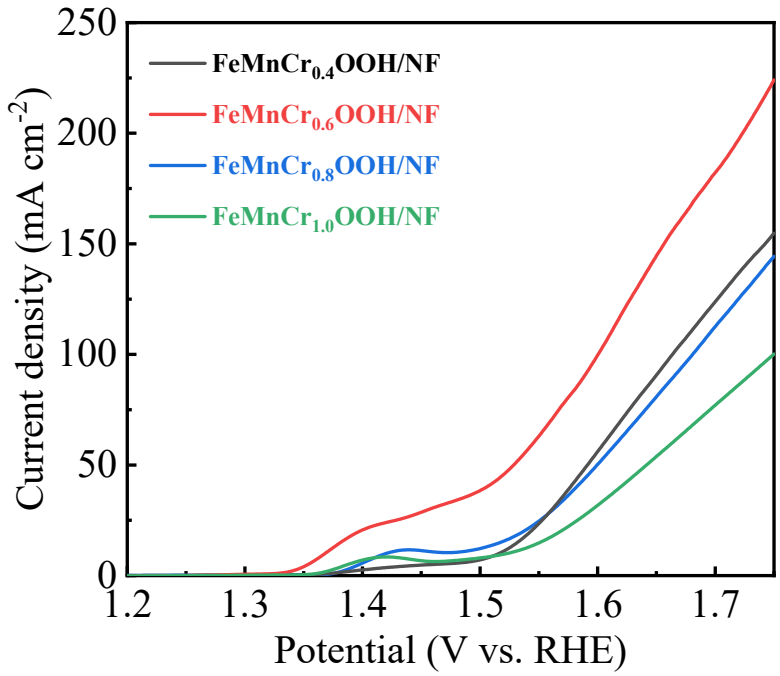

Fig. S6. (a) OER polarization curves of $FeMnCr_nOOH/NF$ (n = 0.4-1.0) at a scan rate of 5 mV s^{-1} in 1M KOH.

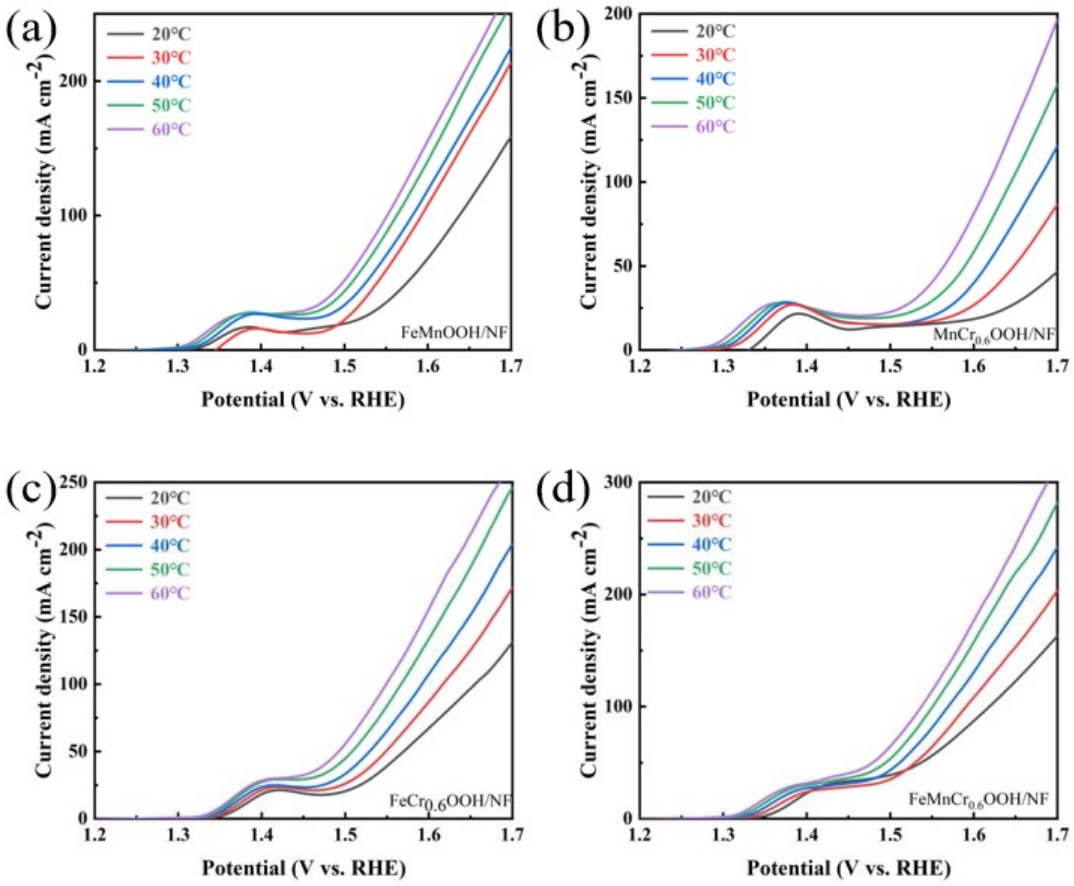

Fig. S7. OER polarization curves of FeMnOOH/NF, $MnCr_{0.6}OOH$/NF, $FeCr_{0.6}OOH$/NF and $FeMnCr_{0.6}OOH$/NF in 1 M KOH with scan rate 5 mV s^{-1} at 20°C, 30°C, 40°C, 50°C, and 60°C.

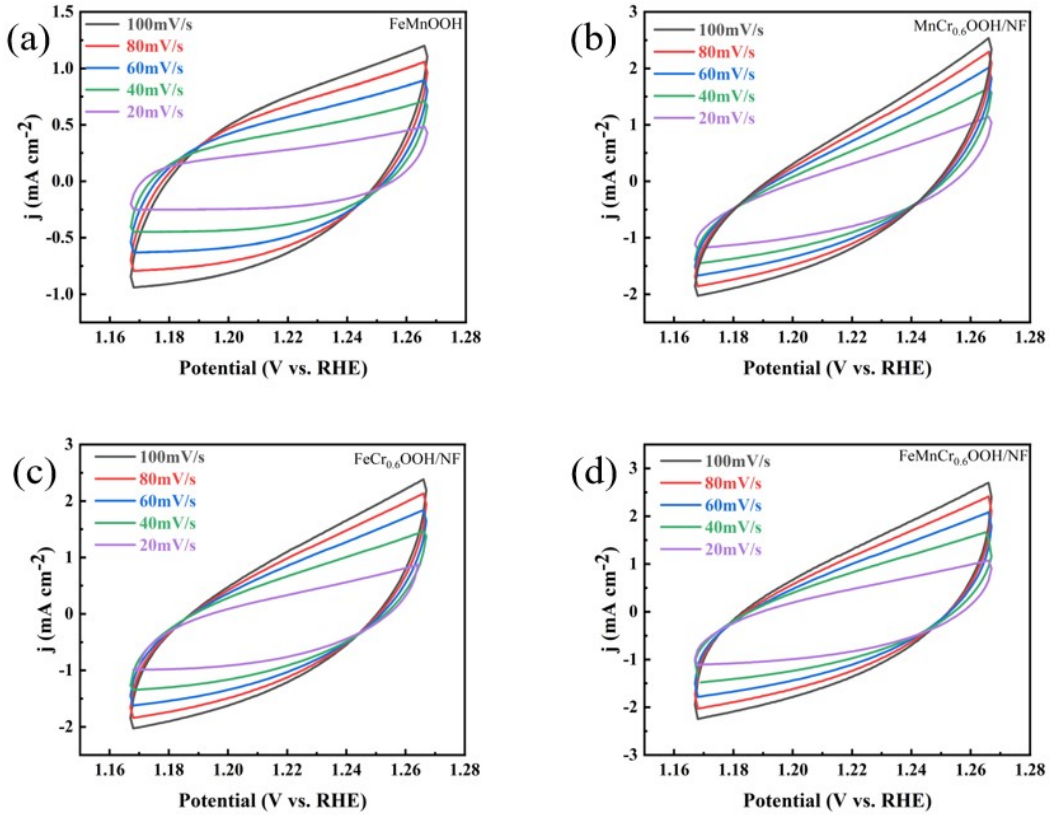

Fig. S8. CVs of (a) FeMnOOH/NF, (b) $MnCr_{0.6}OOH$/NF, (c) $FeCr_{0.6}OOH$/NF, and (d) $FeMnCr_{0.6}OOH$/NF measured in a non-Faradaic region at different scan rate in 1 M KOH.

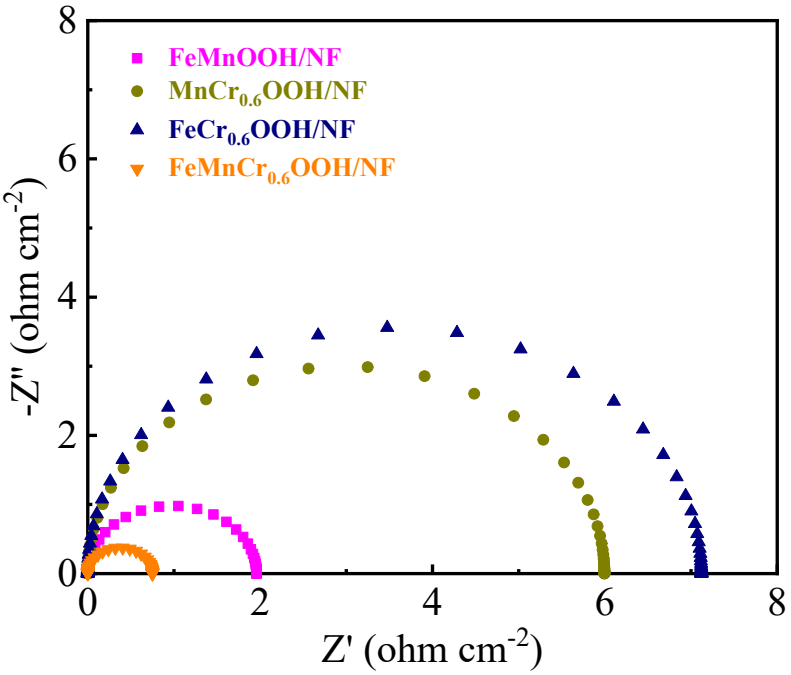

Fig. S9. Nyquist plots of the EIS test for the FeMnOOH/NF, $MnCr_{0.6}OOH$/NF, $FeCr_{0.6}OOH$/NF, and $FeMnCr_{0.6}OOH$/NF.

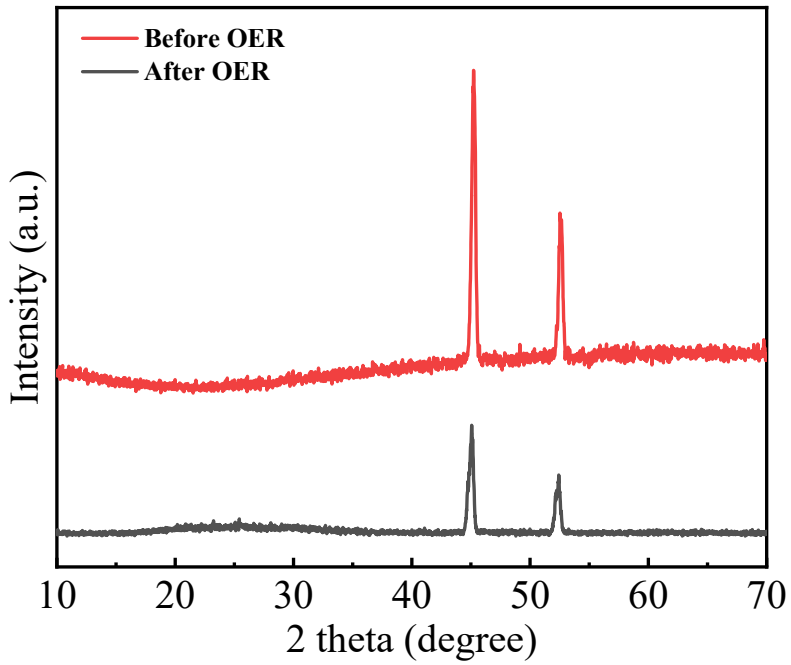

Fig. S10. XRD patterns of $FeMnCr_{0.6}OOH$/NF before and after OER.

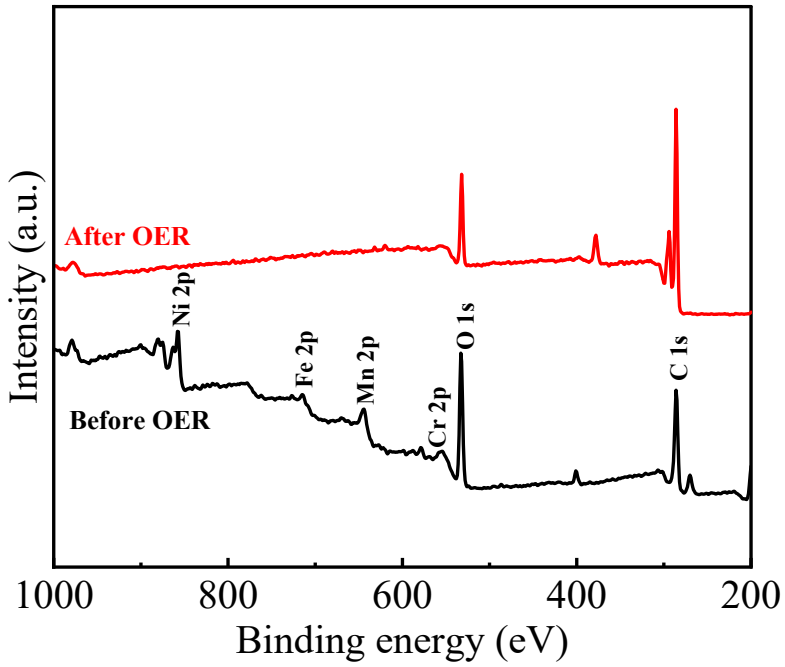

Fig. S11. XPS spectra of $FeMnCr_{0.6}OOH$/NF before and after OER.