Supporting Information

Boosting the OER Activity of Amorphous IrO$_x$ in Acidic Medium by Tuning its Electron Structure Using Lanthanum Salt Nanosheets

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Materials characterizations

The morphology and composition of the materials were characterized by SEM, TEM, XRD, XPS, XANES and EXAFS measurements. The Rigaku diffraction system (D/Max2000) was used to record the XRD patterns of the prepared catalysts. The microstructures and morphology of catalysts were measured by the scanning electron microscope (Hitachi S-4800). The JEOL JEM-2100F transmission electron microscope was used to perform the TEM and HRTEM measurements. Thermo Scientific ESCALAB 250Xi X-ray photoelectron spectrometer was used to detect the electronic structure and chemical state of Ir and O elements in catalyst structure. The XANES of Ir L_{III}-edge and La L_{III}-edge were measured at room temperature by the BL10c beam line at the Pohang Light Source (PLS-II), Korea.

Electrochemical measurement

In a typical three-electrode system, the 0.1 M $HClO_4$ solution was used as the electrolyte. The working electrode was prepared by loading of 5 μL of the catalyst ink on a glassy carbon (GC: 3 mm in diameter). Carbon rod and Ag/AgCl were used as counter and reference electrodes, respectively. The working electrode was prepared according to the steps below: First, the prepared catalyst powder (2 mg) was added into 100 μL of deionized water and 200 μL ethanol with 40 μL of 5 wt % Nafion solution. Next, 1mg of carbon black (XC-72) was added to the formulated ink. The polarization curves were measured in the potential range of 1.20 V to 1.70 V (vs RHE) and the scanning speed was 5 mV s^{-1}. All data were compensated with iR (95%). ESI measurements were made at an open circuit potential in the frequency range of 100 kHz to 0.1 Hz. The durability testing was performed by a chronopotentiometry method at a current density of 10 mA cm^{-2}. The activity and stability of commercially available IrO_2 (Macklin, 99.9%) for OER was determined under the same condition.

Measurement of the Faraday Efficiency: A piece of Ti mesh coated by 1 mg IrO_x/$LaCO_3OH$ (surface area = 1 cm^2) was used as the working electrode. Before measurement, the cell was purged by N_2 gas for about 20 min to to detect the air tightness of the cell. A linear relationship between the O_2 and N_2 gas flow rate and its GC peak area ratio was obtained by plotting five GC measurements of adjust flow rate O_2 samples with fixed flow rate of N_2 is 5 sccm. The GC measurements were measured by FULI INSTRUMENTS GC 9790 plus gas chromatograph.

The GC peak area has a relationship: A (oxygen product) = [A (oxygen 600 s) − A (oxygen 0 s)], as shown in Fig. S6. Therefore, A (N_2/O_2) = A(nitrogen 600s)/A[(oxygen 600s) − A (oxygen 0s)] =4518290/[88888.4-29650.8] =76.27. Take this ratio into the linear equation. O_2 flow rate = 5/[1.965*76.27-0.36899] = 0.03345 sccm. The product amount is n_{O2} = 0.03345*10*10^{-3}/22.45 = 1.49 µmol. After 600s, amount of charge transferred by reaction were 6.0189C. The ideal product amount is n(O_2,theoretical) =C/F/4 = 6.0189/(96485*4) = 1.56 µmol, where C is the amount of charge transferred, F is the faraday constant (96485 C mol^{-1}). Therefore, the Faraday efficiency is n(O_2,experimental)/n(O_2,theoretical)×100% = 1.49/1.56*100% = 95.5%.
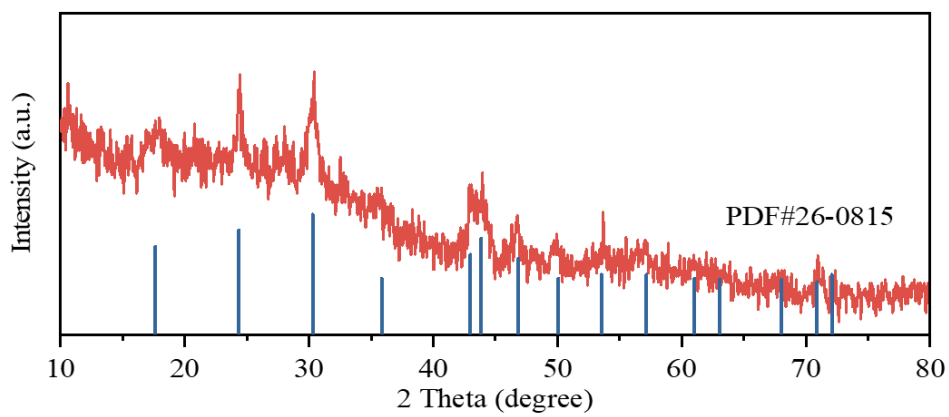
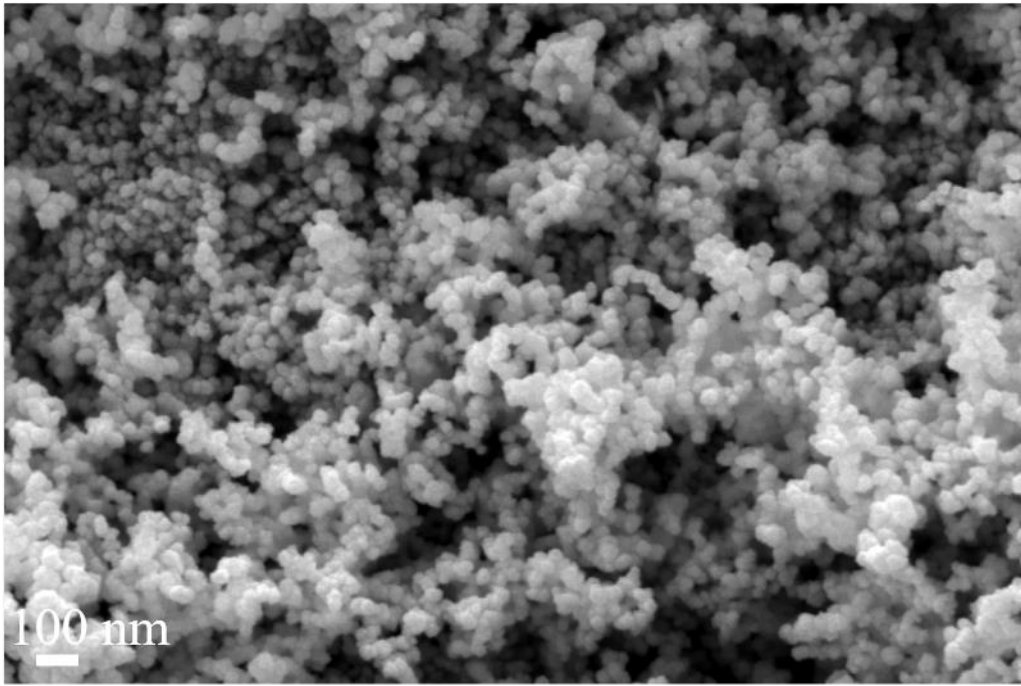**Fig. S1** The XRD pattern of the IrO_x/$LaCO_3OH$.

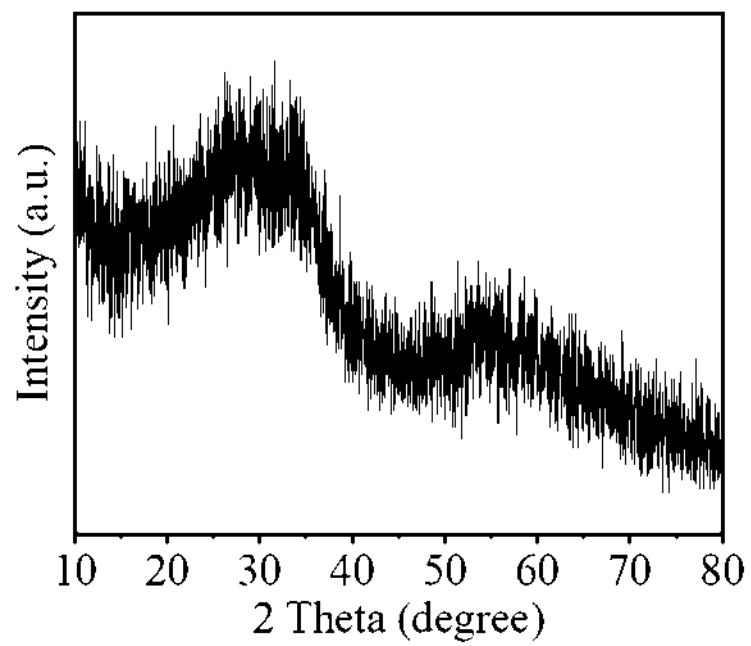**Fig. S2** The SEM pattern of the amorphous IrO_x.
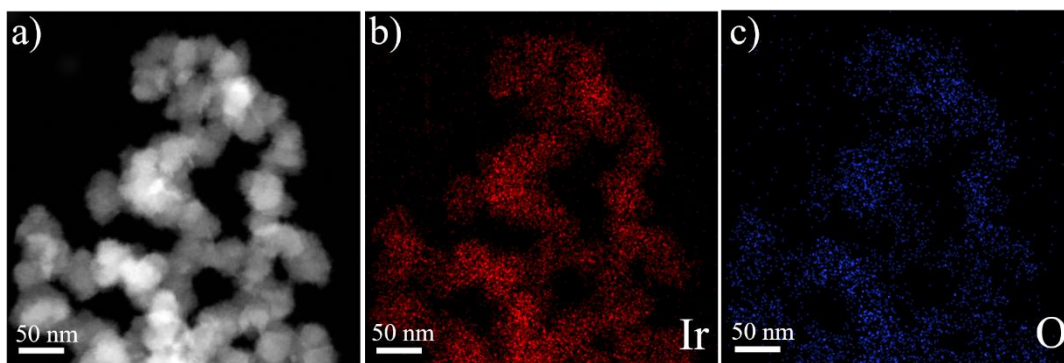
Fig. S3 The XRD pattern of the Amorphous IrO$_x$.

Fig. S4 HAADF-STEM image of the Amorphous IrO_x and the corresponding elemental mappings of Ir, and O.
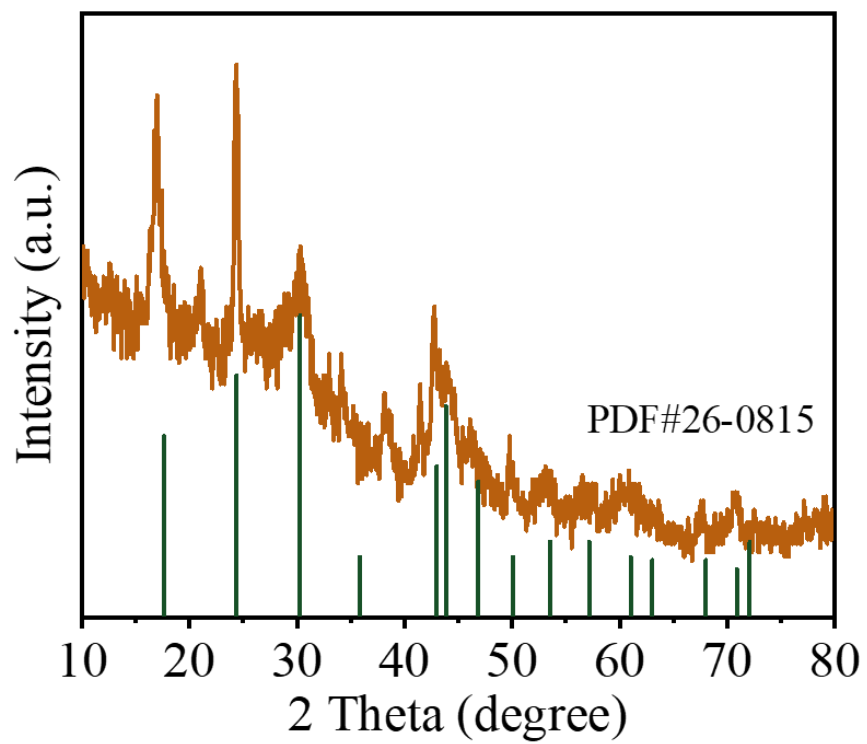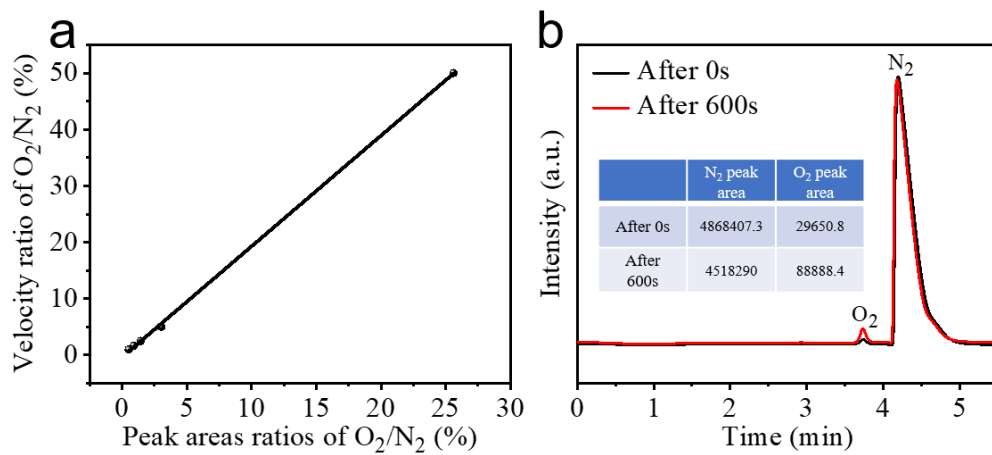
Fig. S5 The XRD pattern of the LaCO$_3$OH.

Fig. S6. (a) The linear relationship between the velocity ratio of O_2/N_2 and its GC peak area ratio. (b) GC profiles of O_2 and N_2 for $IrO_x/LaCO_3OH$ after 0 and 600 s electrolysis.
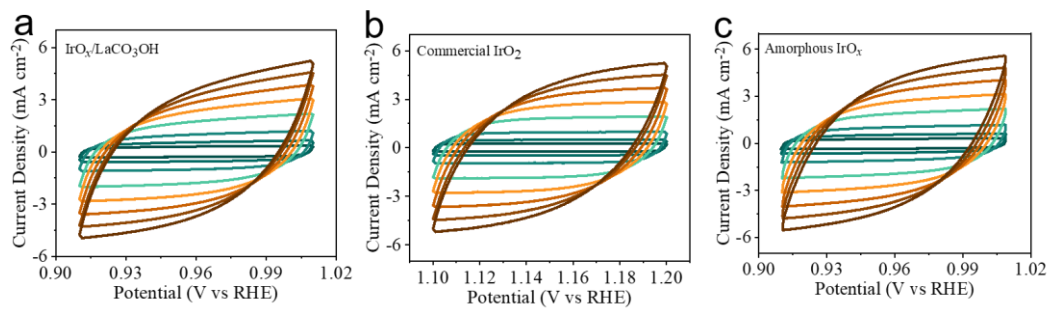
Fig. S7 Cyclic voltammograms recorded at various scan rates (10 ~ 120 mV s^{-1}) for determining the double layer capacitance: (a) IrO$_x$/LaCO$_3$OH, (b) Commercial IrO$_2$, (c) Amorphous IrO$_x$.
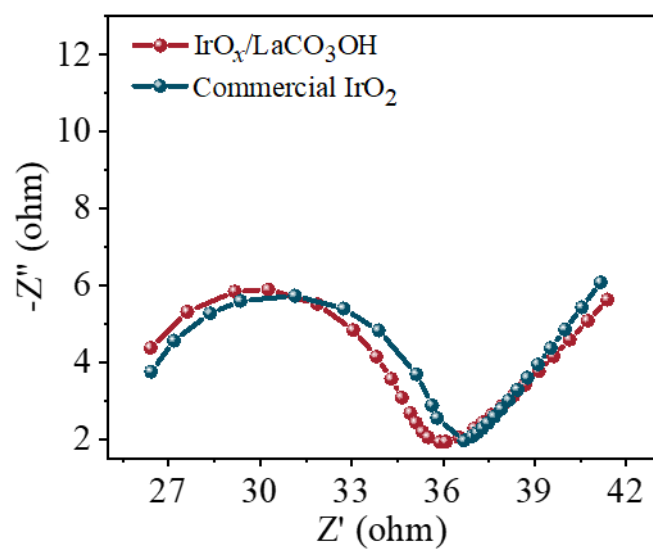
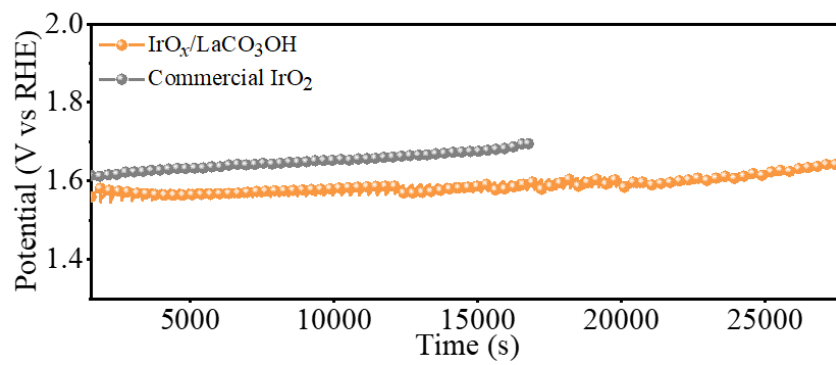**Fig. S8** Nyquist plots of electrochemical impedance spectra (EIS) of the IrO$_x$/LaCO$_3$OH.

Fig. S9 Long-term chrono potentiometric curves of IrO$_x$/LaCO$_3$OH and Commercial IrO$_2$ at 10 mA cm^{-2}.

Fig. S10 Cyclic voltammograms recorded at various scan rates (10 ~ 120 mV s^{-1}) for determining the double layer capacitance: (a) IrO$_x$/LaCO$_3$OH-3:1, (b) IrO$_x$/LaCO$_3$OH -4:1 and (c) The double-layer capacitances of catalysts prepared at different molar ratios.

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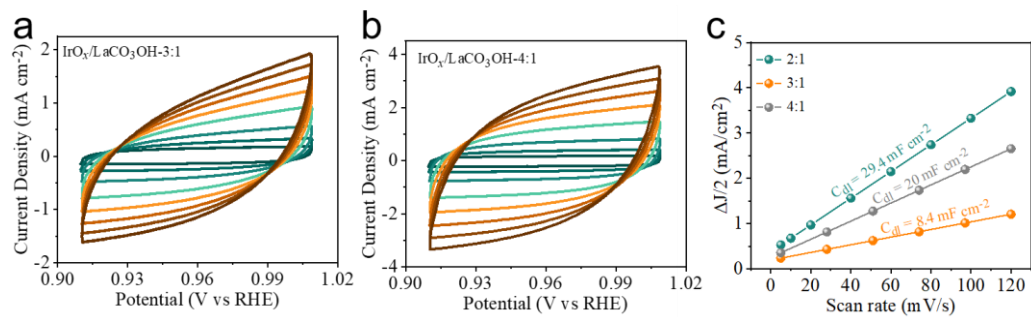
molar ratios.

Fig. S12 Cyclic voltammograms recorded at various scan rates (10 ~ 120 mV s^{-1}) for determining the double layer capacitance: (a) IrO$_x$/LaCO$_3$OH-160℃ and (b) The double-layer capacitances of catalysts prepared at different temperatures.
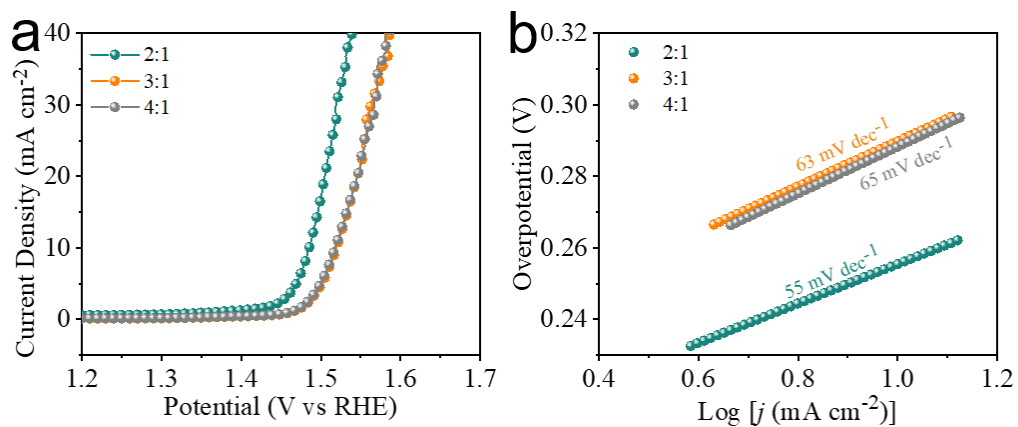
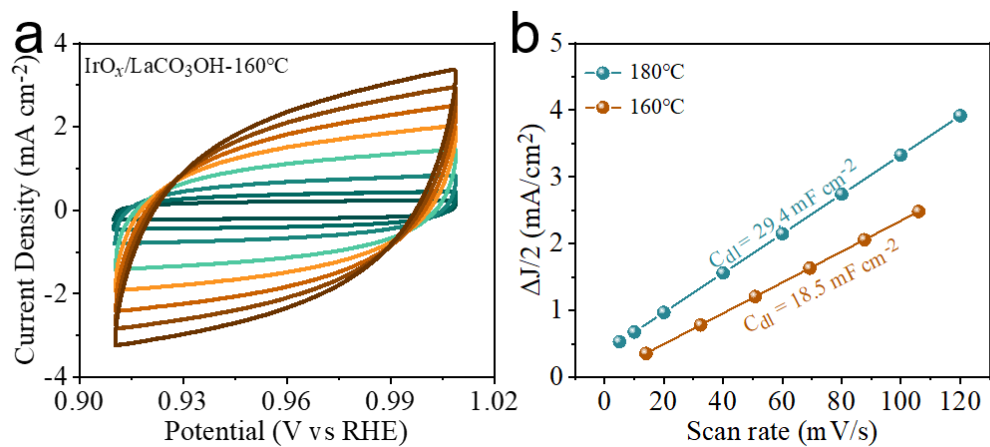**Fig. S13** (a) Polarization curves and (b) Tafel slopes of catalysts prepared at different temperatures.

Fig. S14 Cyclic voltammograms recorded at various scan rates (10 ~ 120 mV s^{-1}) for determining the double layer capacitance: (a) IrO$_x$/LaCO$_3$OH-12 h, (b) IrO$_x$/LaCO$_3$OH-36 h and (c) The double-layer capacitances of catalysts prepared at different reaction times.

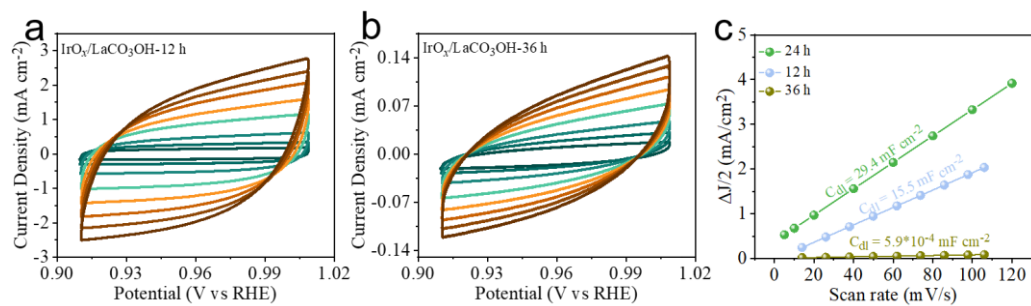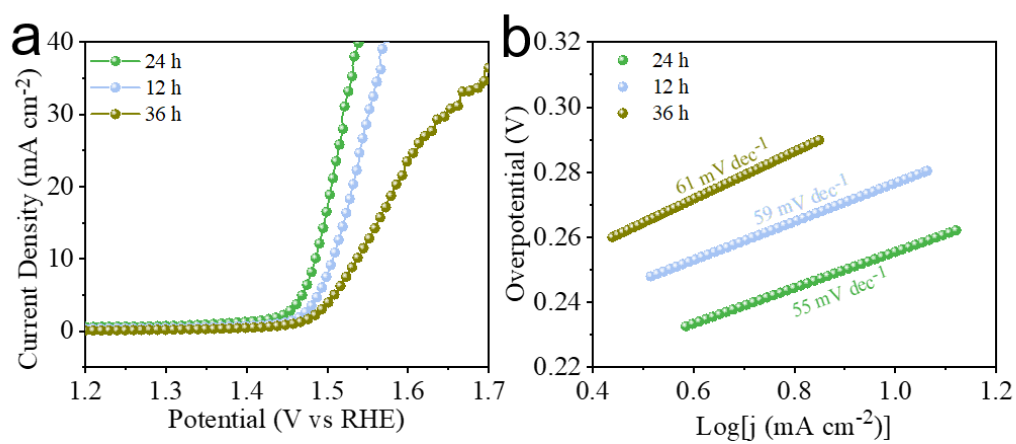**Fig. S15** (a) Polarization curves and (b) Tafel slopes of catalysts prepared at different reaction times.

Fig. S16. SEM image of catalysts prepared with reaction for (a) 12 h and (b) 36 h.

Table S1 Comparison of the overpotentials at 10 mA cm^{-2} with recently reported

OER catalysts in acidic media

Electrocatalyst	Electrolyte	Overpotential(mV) at 10 mA cm^{-2}	References
Commercial RuO$_2$	0.1 M HClO$_4$	315	This work
IrO$_x$/LaCO$_3$OH	0.1 M HClO$_4$	255	This work
NiIrRuAl-1/3	0.1 M HClO$_4$	237	[1]
6H-SrIrO$_3$	0.5 M H$_2$SO$_4$	248	[2]
La-Ir NF	0.1 M HClO$_4$	263	[3]
SrIrO-1100	0.5 M H$_2$SO$_4$	263	[4]
RuCu	0.5 M H$_2$SO$_4$	270	[5]
IrCuNi DCNCs	0.1 M HClO$_4$	273	[6]
Ni$_{0.34}$Co$_{0.46}$Ir$_{0.2}$O$_\delta$	0.1 M HClO$_4$	280	[7]
IrCo	0.5 M H$_2$SO$_4$	284	[8]
Ir$_{0.4}$Mn$_{0.6}$O$_\delta$	0.1 M H$_2$SO$_4$	285	[9]
Sr$_2$IrO$_4$	0.1 M HClO$_4$	286	[10]
La$_3$IrO$_7$-SLD	0.1 M HClO$_4$	296	[11]
Ir$_{0.06}$Co$_{2.94}$O$_4$	0.1 M HClO$_4$	300	[12]
IrO$_x$-03	0.1 M HClO$_4$	300	[13]
IrO$_x$/Pr$_3$IrO$_7$	0.1 M HClO$_4$	305	[14]
IrNiO$_x$ TF	0.1 M HClO$_4$	315	[15]
Ir/Co$_4$N	0.5 M H$_2$SO$_4$	319	[16]

0.5IrO$_2$-0.5SiO$_2$	0.5 M H$_2$SO$_4$	322	[17]
IrNi/NiO HT	0.1 M HClO$_4$	329	[18]
Ir$_{0.7}$Co$_{0.3}$O$_x$	0.5 M H$_2$SO$_4$	330	[19]
IrNiO$_x$	0.1 M HClO$_4$	332	[18]
Ir HT	0.1 M HClO$_4$	336	[18]
Ir$_{0.3}$Mo$_{0.7}$O$_\delta$	0.1 M HClO$_4$	345	[20]
Ir/Ni$_4$N	0.5 M H$_2$SO$_4$	346	[16]
Ba$_2$YIrO$_6$	0.1 M HClO$_4$	350	[21]
K$_{x\approx0.25}$IrO2	0.1 M HClO$_4$	350	[22]
SrIrO$_3$	0.1 M HClO$_4$	353	[10]
Bi$_2$Ir$_2$O$_7$	1 M H$_2$SO$_4$	365	[23]
RuIrCoO$_x$	0.5 M H$_2$SO$_4$	394	[24]

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