Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Atomic Iridium@Cobalt Nanosheets for Dinuclear Tandem Water Oxidation

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Supporting Information

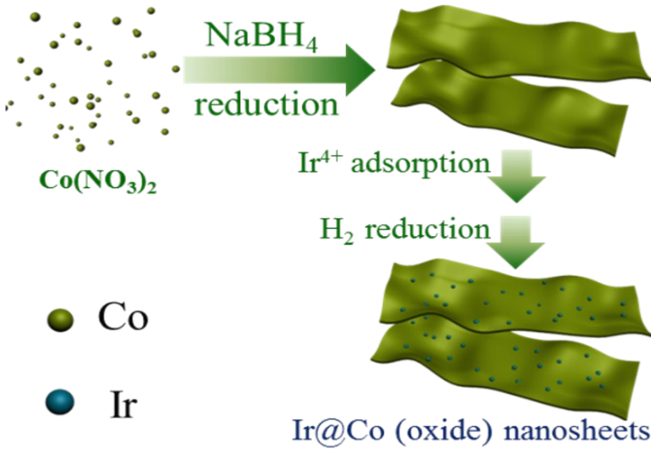

Figure S1 Schematic illustration of the synthesis of Ir@Co nanosheets.

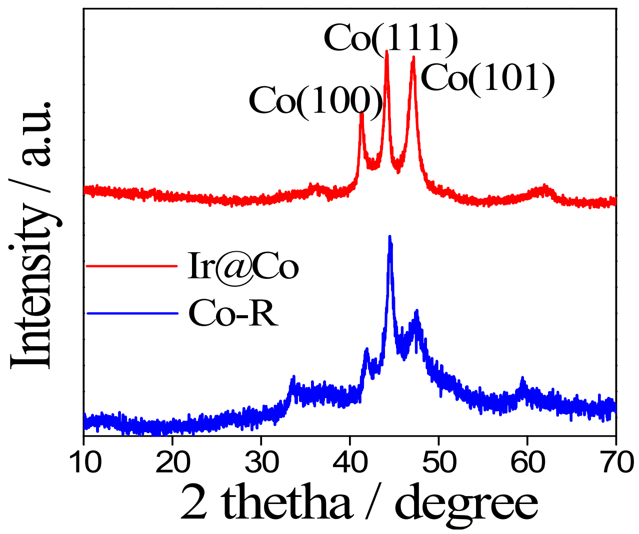

Figure S2 XRD patterns of Co-R and Ir@Co.

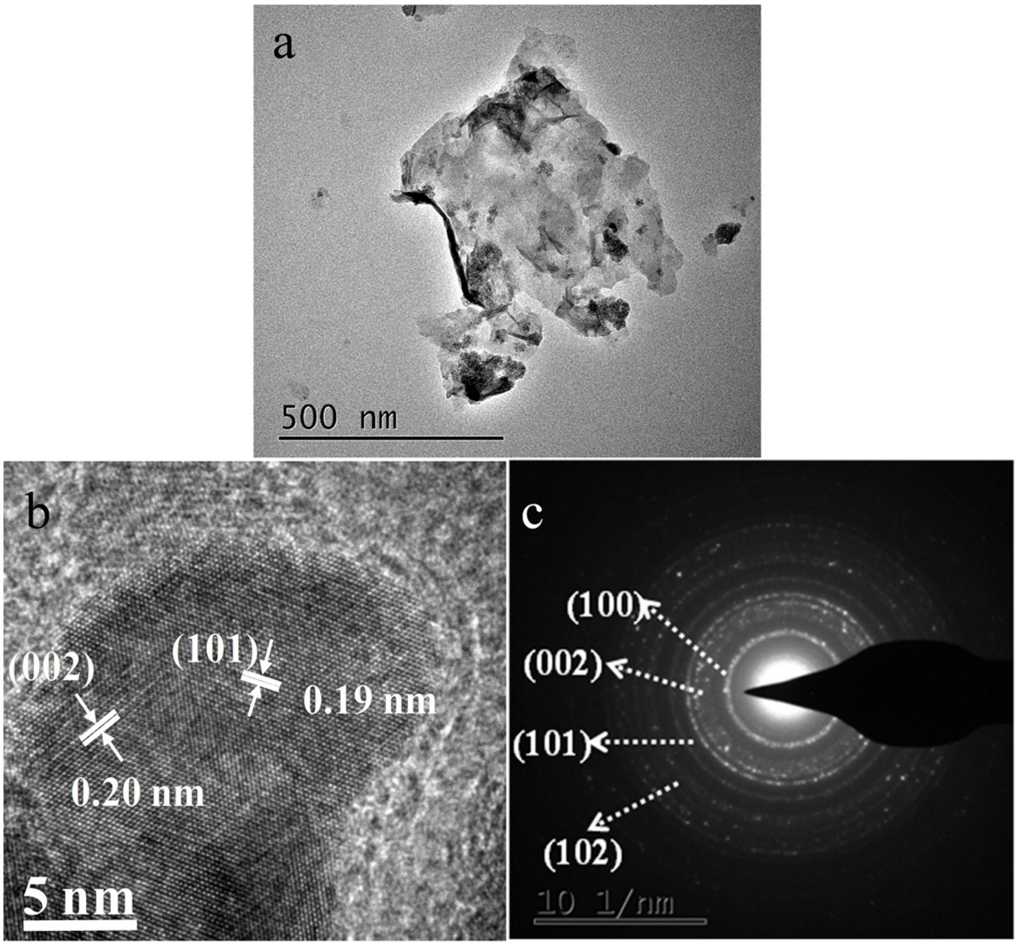

Figure S3 (a,b) Low- and high-magnification transmission electron microscopy (TEM) images and (c) selected area electron diffraction (SAED) of Ir@Co nanosheets.

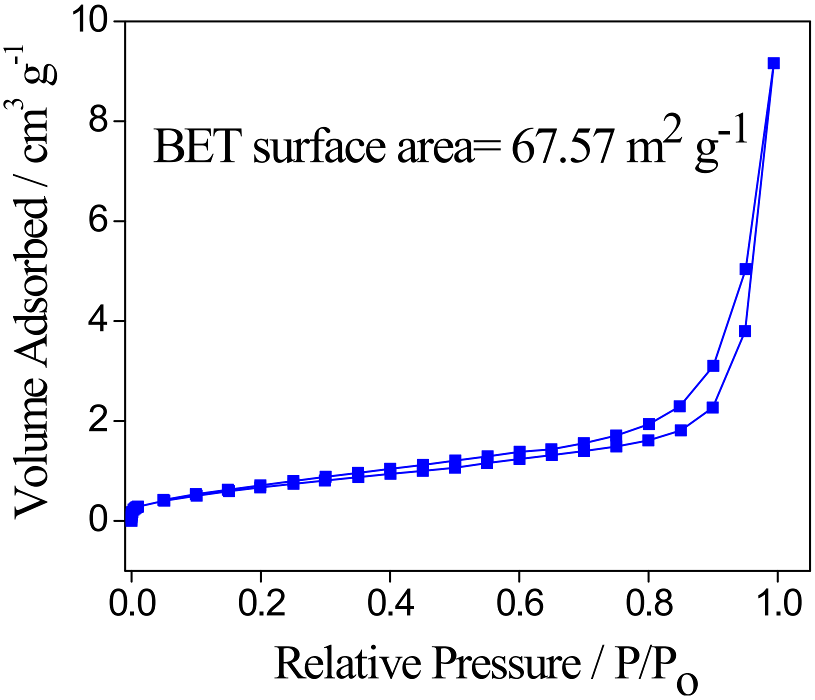

Figure S4 N_2 adsorption-desorption isotherm of the 2DIr@Co nanosheets for determination of the Brunauer–Emmett–Teller (BET) surface area.

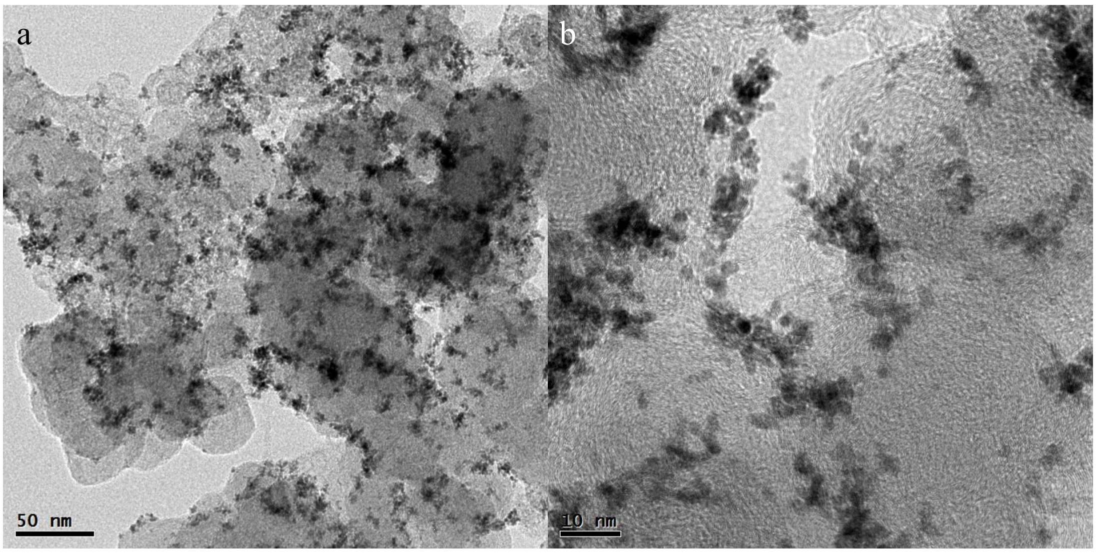

Figure S5 (a,b) Low- and high-magnificationTEM images of Ir/C material.

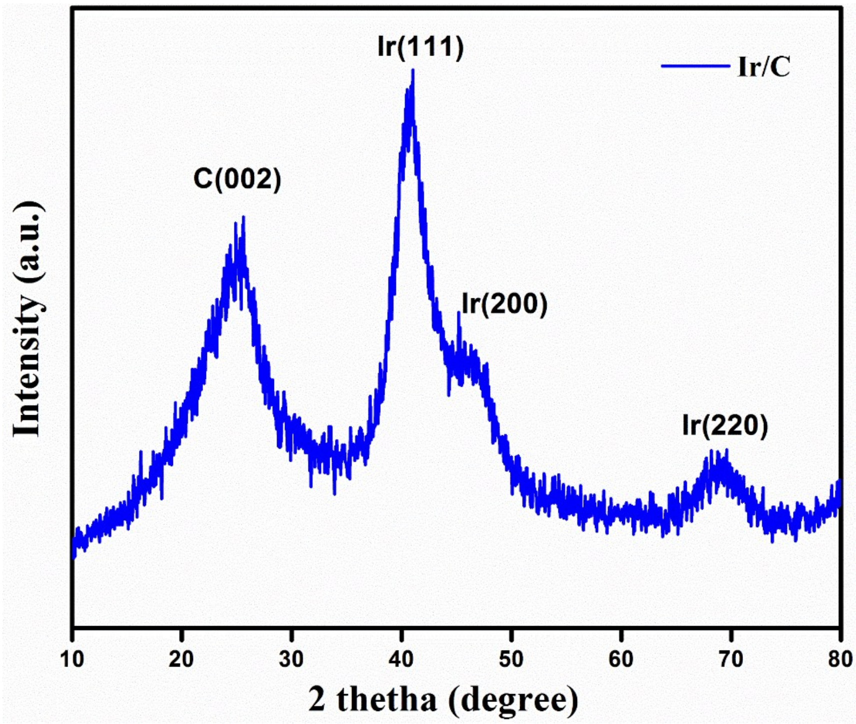

Figure S6 X-Ray Powder Diffraction of Ir/C.

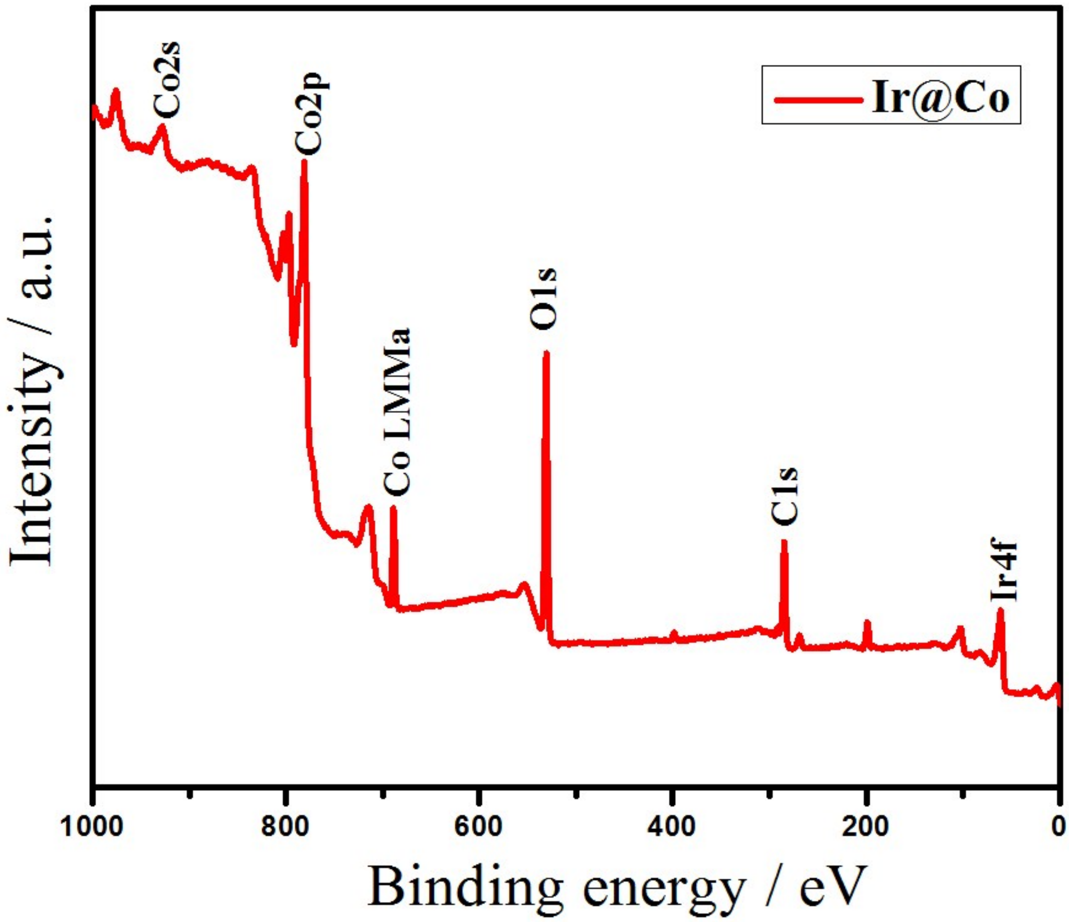

Figure S7 The survey XPS spectrum of Ir@Co.

Table S1. Contents of O1~O4 in the materials as determined by XPS analysis.

	Ir@Co (at.%)	Co-A(at.%)	Co-R (at.%)
O1	1.7	24.1	4.4
O2	18.3	39.5	28.1
O3	33.1	25.3	25.1
O4	46.9	11.2	32.4

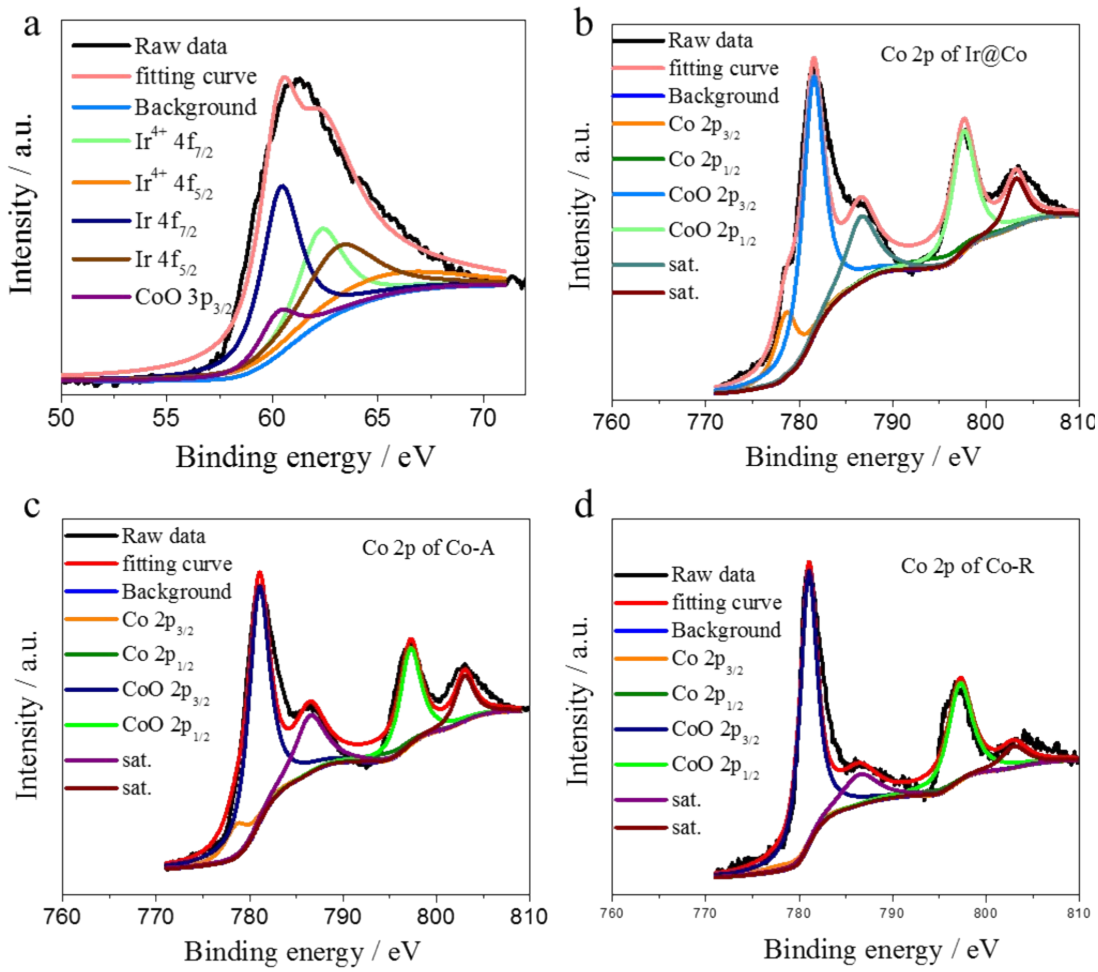

Figure S8 High-magnification XPS spectra in (a) Ir 4f region of Ir@Co, (b) Co 2p region of Ir@Co, (c) Co 2p region of Co-A and (d) Co 2p region of Co-R.

Table S2 Fitting parameters of EXAFS data.

Sample	Ir-Co		D. W.	ΔE_0 (eV)
	R (Å)	CN		
Ir@Co	2.55±0.01	8.8±1.2	0.005±0.001	8.4±2.1

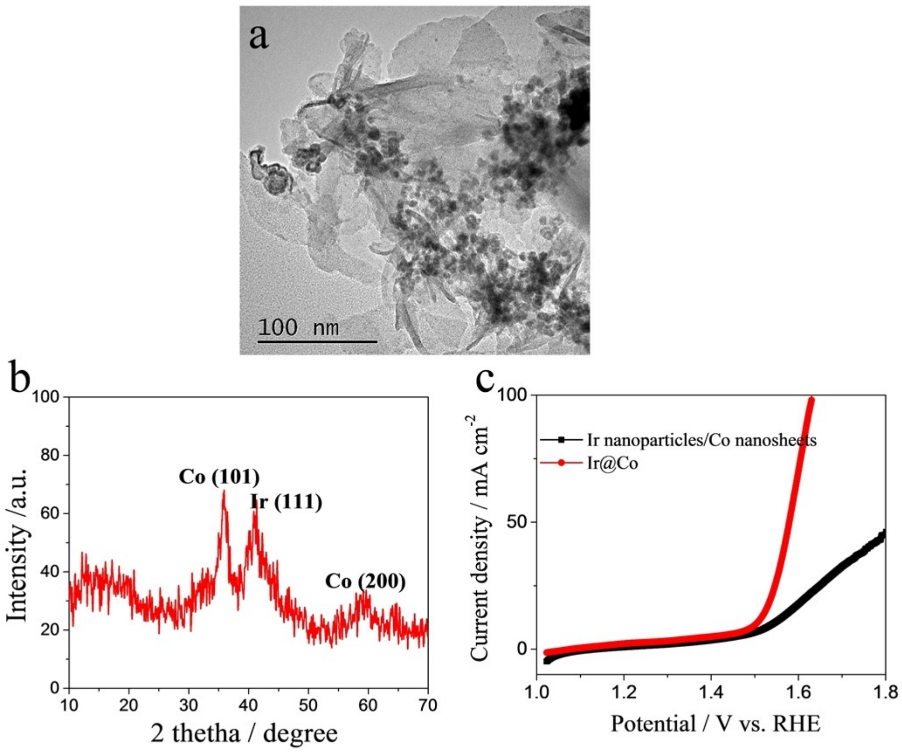

Figure S9 (a) TEM image of Ir nanoparticles/Co nanosheets. (b) XRD of Ir nanoparticles/Co nanosheets. (c) LSV curves for Ir@Co and Ir nanoparticles/Co nanosheets.

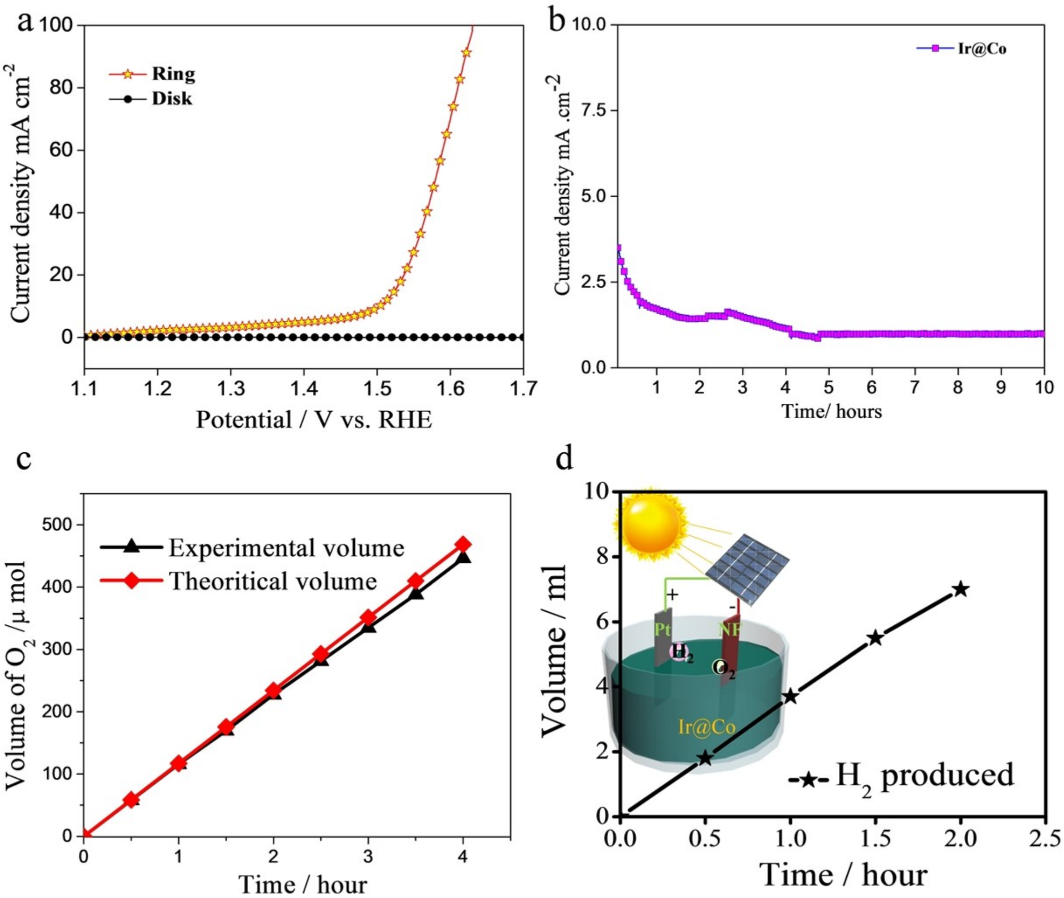

Figure S10 (a) Rotating ring-disk electrode (RRDE) test of Ir@Co in 1 M KOH solution with IR corrections; (b) chronoamperometry test of Ir@Co sample; (c) O_2 production volumes as a function of water-oxidation time. (d) Hydrogen production along with electrolysis time by solar cell-driven overall water splitting, using a commercial planar polycrystalline Si solar cell and a Pt plate as the counter electrode.

Table S3 Comparison in OER performance of some noble metal-based catalysts reported recently in literature.

Source/References	Solution	Loading	Tafel slope value mV dec^{-1}	Overpotential at 10 mA cm^{-2} (mV)
***This work* (Ir@Co)**	**1 M KOH**	**0.0034 mg_{Ir} cm^{-2}**	**99**	***273***
J. Am. Chem. Soc., 2015, 137, 13031–13040 (Ir-Ni oxide)	0.1 M $HClO_4$	-	-	*305*
Angew. Chem. Int. Ed., 2016, 55, 742–746 (IrO_x-Ir)	0.5 M H_2SO_4	1 mg_{Ir} cm^{-2}	*43.7–44.7*	*295*
Angew. Chem. Int. Ed.,2015, 54, 2975–2979. ($IrNiO_x$)	0.05 M H_2SO_4	0.01 mg_{Ir} cm^{-2}	-	*280*
Science, 2016, 353,1011-1014. ($IrO_x/SrIrO_3$)	0.5 M H_2SO_4	Pure $SrIrO_3$ film electrode	-	*270-290*
Chem. Sci., 2015, 6, 3321-3328 (Irnanodendrites)	0.05 M H_2SO_4	0.01 mg_{Ir} cm^{-2}	*55.6-57.0*	*280*
Nano Lett., 2016, 16, 4424–4430 (Ultrathin Laminar Ir)	1 M KOH	0.01 mg_{Ir} cm^{-2}	*32.7*	*242*
Adv. Mater. 2017, 29, . https://doi.org/10.1002/adma.201703798 (IrCoNi)	0.1 M $HClO_4$	0.01 mg_{Ir} cm^{-2}	*53.8*	*303*
Adv. Mater. Interfaces 2018, 1800392 (Co/N-CNTs@Ti_3C_2T)	0.1 M KOH	0.408 mg cm^{-2}	*79.1*	*410*
Advanced Materials, 2017, 29, 1606793 (Fe_1Co_1-ONS)	0.1 M KOH	0.36 mg cm^{-2}	*36.8*	*308*
Adv. Funct. Mater. 2017, 27, 1606497 (PPy/FeTCPP/Co)	0.1 M KOH	0.3 mg cm^{-2}	*61*	*340*
Advanced Science, 2018, 5, 1801029 (2D cobalt-based ZIF-9(III) nanosheets)	1 M KOH	0.21 mg cm^{-2}	*55*	*380*

Note: -represents not mentioned in the literature. All the potentials are calibrated and converted to reversible hydrogen electrode.

For Faradic efficiency calculation

Water splitting Potential: 2.0 V

Table S3. H_2 production and current change along withelectrolysis time in solar-assisted water oxidation on Ir@Co nanosheet electrode.

Time / h	H_2 / ml	Current / mA	Potential / V
0.5	2.4	10.2	
1	3.95	9.6	
1.5	5.5	8.6	
2	7.0	6.4	
Average		8.7	2.0

H_2 in practice:0.007 L/ 22.4 L/mol = 3.125 * 10^{-4}mol H_2

H_2 in theory: (8.7* 10^{-3}A * 7200 s) / 96500*2 = 104850 * 10^{-3} / 193000mol = 3.24* 10^{-4}mol H_2

Faradic Efficiency = 3.125 * 10^{-4} / 3.24* 10^{-4} = 96.4 %

Forsolar to hydrogen effciency

Energy of solar: 0.00145 m^2 * 1000 W/m^2 * 7200 s= 10440 W

Energy from H_2: U*I*7200 s* Faradic Efficiency= 2.0 V*8.7*10^{-3}*7200 s* 0.964 124.3

Solar to hydrogen effciency = 124.3/ 10440 = 0.0119 or 1.19 %

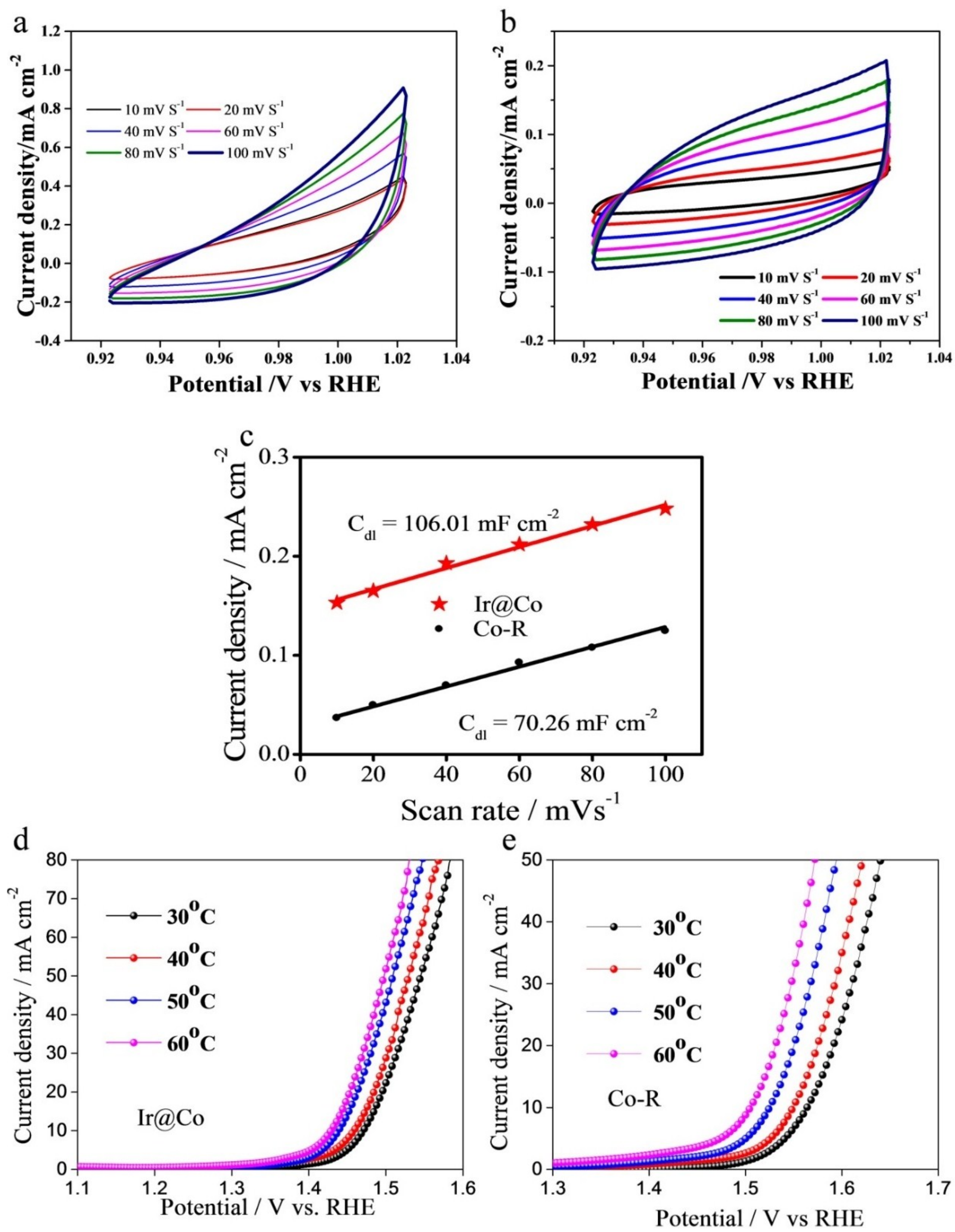

Figure S11 CVs of (a)Ir@Co and (b) Co-R measured in a non-Faradaic region at scan rate of 10 mV s^{-1}, 20 mV s^{-1}, 40 mV s^{-1}, 60 mV s^{-1}, 80 mV s^{-1}, and 100 mV s^{-1}, for determining the electrochemical active surface area of Ir@Co nanosheets and Co-R. (c) Electrochemical double-layer capacitance measurements (currents measured at 0.1 V vs. RHE as a function of scan rate) for Ir@Co and Co-R. (d and e) LSV curves for OER at different temperature.

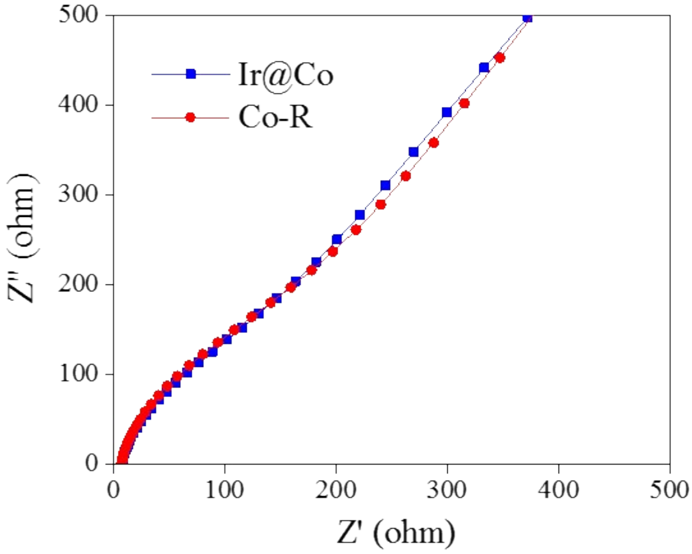

Figure S12 Electrochemical impedance spectroscopies (EISs) of Ir@Co nanosheet and Co-R.

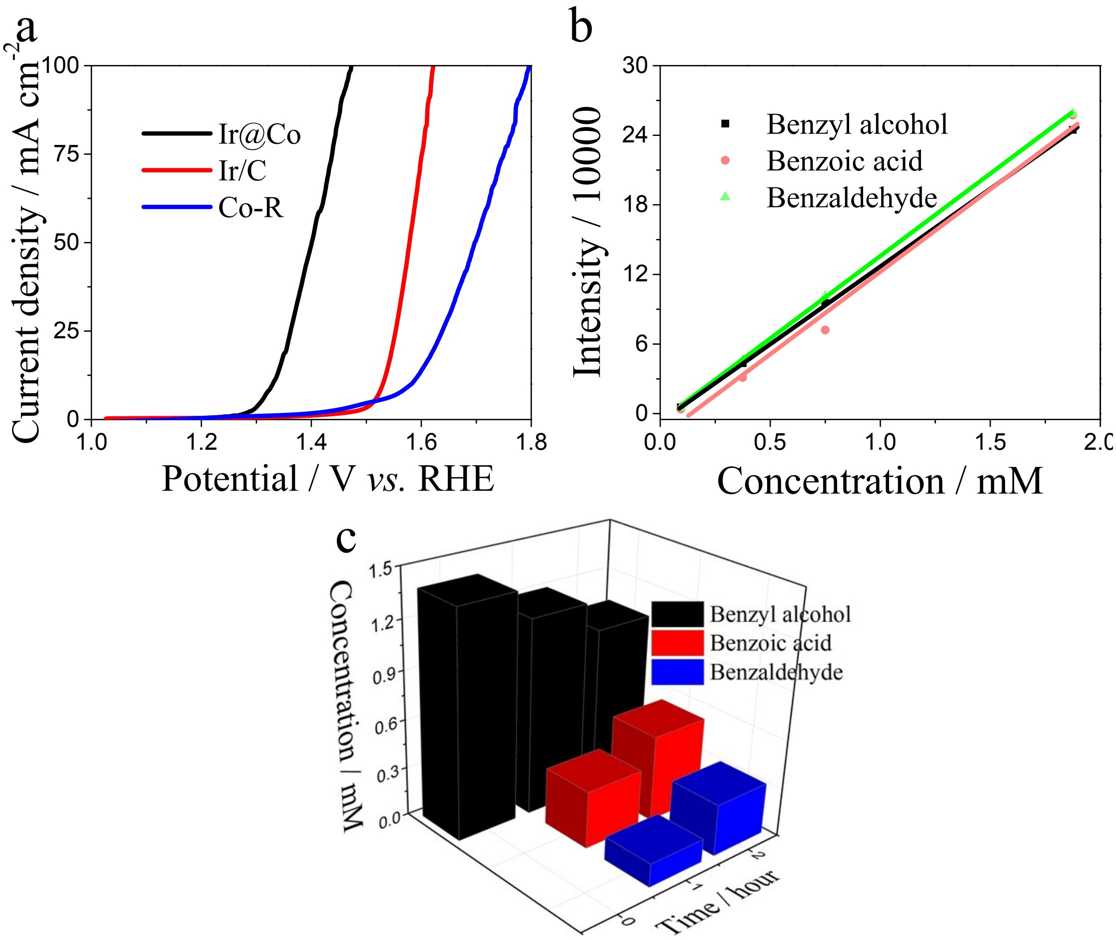

Figure S13 (a) LSV curves in 1 M KOH with 12.5 mM benzyl alcohol (BA) on the catalysts; and (b) standard curves for benzyl alcohol, benzaldehyde and benzoic acid. (c) shows the amount of benzyl alcohol, benzaldehyde and benzoic acid at 0, 1 and 2 hours.

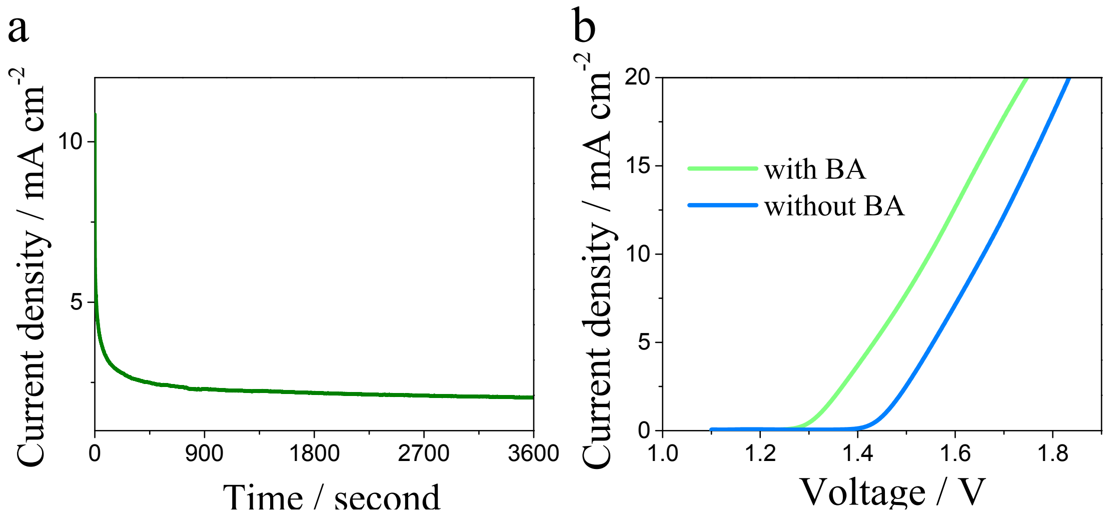

Figure S14 (a) Current-time curve at -0.5 V on Ir@Co material; (b) water splitting with and without BA.

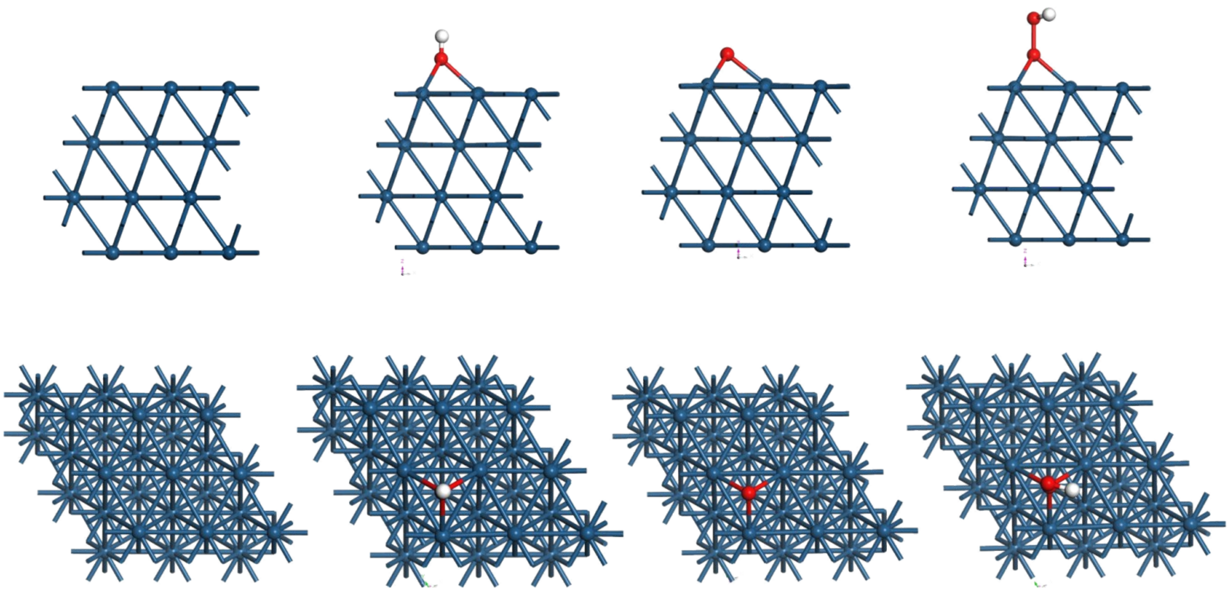

Figure S15 The OER processes on Ir/C model.