

### Supplementary Information

Graphynes: the ideal supports of single atoms for electrochemical energy conversion

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Table S1 The performance of GYs-supported SCAs and other various electrocatalysts for ORR.

Electrocatalysts	Electrolyte	Mass loading (mg cm <sup>-2</sup> )	Onset potential (V)	Half-wave potential (V)	Tafel slope (mV dec <sup>-1</sup> )	Stability	References
Fe-GDY	0.1 M KOH	0.49	0.98	0.87	63	12 h	1
NiFe-DG	0.1 M KOH	0.38	0.97	0.86	71	5000 cycles	2
Fe-PBC	0.1 M KOH	0.15	1.01	0.86	-	1000 h	3
NPCTC	0.1 M KOH	0.10	0.92	0.83	-	10000 s	4
Fe@MNC-1	0.1 M KOH	0.05	1.01	0.88	54	10000 s	5
Fe-NCCs	0.1 M KOH	0.10	0.93	0.82	-	10000 cycles	6
Fe <sub>1</sub> Co <sub>1</sub> -CNF	0.1 M KOH	0.20	0.99	0.87	88	10000 s	7
FeCo-N-HCN	0.1 M KOH	0.10	0.98	0.86	52	35 000 s	8
Co <sub>3</sub> O <sub>4-x</sub> @NSC	0.1 M KOH	-	0.82	0.78	63	1000 cycles	9
Zn,Co-N <sub>x</sub> -C-Sy	0.1 M KOH	0.30	1.07	0.84	50	20000 s	10
FCPA-900	0.1 M KOH	0.40	0.91	0.84	60	30000 s	11

defect Mn <sub>3</sub> O <sub>4</sub>	0.1 M KOH	-	0.87	0.65	98	20000 s	12
Co <sub>9</sub> S <sub>8</sub> @N-S-HPC	0.1 M KOH	0.26	0.99	0.85	75	5000 cycles	13
Co <sub>0.05</sub> N <sub>1</sub> _pCNT	0.1 M KOH	0.20	1.00	0.87	-	5000 cycles	14
FeBNC	0.1 M KOH	0.60	0.97	0.83	69	35000 s	15
CoNC700	0.1 M KOH	0.15	0.96	0.85	78	10000 cycles	16
Mn/C-NO	0.1 M KOH	0.30	-	0.86	-	5000 cycles	17
MnNPC-900	0.1 M KOH	0.25	0.95	0.84	-	10000 s	18
CoN <sub>4</sub> /NG	0.1 M KOH	0.24	0.98	0.87	70	36000 s	19
HNCSs	0.1 M KOH	0.20	0.92	0.82	66	10 h	20
Co@Co <sub>3</sub> O <sub>4</sub> /NC-2	0.1 M KOH	0.25	-	0.81	-	10000 s	21

Table S2 The performance of GYs-supported SCAs and other various electrocatalysts for OWS.

Electrocatalysts	Electrolyte	Mass loading (mg cm <sup>-2</sup> )	Overpotential <sub>10</sub> for HER (mV)	Overpotential <sub>10</sub> for OER (mV)	Cell voltage <sub>10</sub> (V)	Stability	References
Ru/GDY	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.48	44	531	1.81	-	22
Co-doped MoS <sub>2</sub>	0.5 M H <sub>2</sub> SO <sub>4</sub>	2.00	60	540	1.90	50000 s	23
RuO <sub>2</sub> /Co <sub>3</sub> O <sub>4</sub> RuCo@NC	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.35	141	247	1.66	8 h	24
PBAs@PANI	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.35	170	330	1.74	10 h	25
CoP-Mo <sub>2</sub> C@NC/CC	0.5 M H <sub>2</sub> SO <sub>4</sub>	1.80	107	330	1.67	8	26
Ni <sub>5</sub> P <sub>4</sub>	0.5 M H <sub>2</sub> SO <sub>4</sub>	3.50	140	-	1.70	-	27
FeP NTs	0.5 M H <sub>2</sub> SO <sub>4</sub>	1.60	88	-	1.69	14 h	28
ONPPGC/OCC	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.10	109	470	1.77	10 h	29
Ir <sub>6</sub> Ag <sub>9</sub> NTs/C	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.20	20	285	1.55	1000 cycles	30
IrNi <sub>0.57</sub> Fe <sub>0.82</sub>	0.5 M HClO <sub>4</sub>	0.09	24	284	1.64	20000 s	31
AuCu@IrNi	0.1 M HClO <sub>4</sub>	-	13	308	1.59	24 h	32
MoSe <sub>2</sub> /MoO <sub>2</sub> /CNT-M	0.5 M H <sub>2</sub> SO <sub>4</sub>	-	97	-	1.63	10 h	33

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Ultrasmall Ir NPs	0.5 M HClO <sub>4</sub>	0.09	-	290	1.58	20000 s	34
Ir WNWs	0.5 M HClO <sub>4</sub>	0.03	16	270	1.62	40000 s	35
Ir/g-C <sub>3</sub> N <sub>4</sub> /NG	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.07	22	287	1.56	24000 s	36
Ir <sub>2</sub> Ni/C	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.32	30	292	1.60	10000 s	37
IrCoNi PHNC	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.01	68	309	1.56	1000 cycles	38
NC-CNT/CoP	0.5 M H <sub>2</sub> SO <sub>4</sub>	1.5	62	400	1.65	20 h	39
IrCo Nanodendrite	0.1 M HClO <sub>4</sub>	0.09	17	281	1.60	20000 s	40

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Table S3 The performance of GYs-supported SCAs and other various electrocatalysts for NRR.

Electrocatalysts	Electrolyte	Mass loading (mg cm <sup>-2</sup> )	Ammonia yield (μg h <sup>-1</sup> mg <sub>cat.</sub> <sup>-1</sup> )	FE (%)	Stability	References
Mo <sup>0</sup> /GDY	0.1 M Na <sub>2</sub> SO <sub>4</sub>	-	145.4	21.0	-	41
Mo <sup>0</sup> /GDY	0.1 M HCl	-	2.0	15.6	-	41
Pd <sup>0</sup> -GDY	0.1 M Na <sub>2</sub> SO <sub>4</sub>	0.0027	4450	31.6	6 cycles	42
Pd <sup>0</sup> -GDY	0.1 M HCl	0.0027	1580	4.3	6 cycles	42
Pt SAs/WO <sub>3</sub>	0.1 M K <sub>2</sub> SO <sub>4</sub>	0.60	342.4	31.1	10 cycles	43
ISAS-Fe/NC	0.1 M PBS	1.00	62.9	18.6	24 h	44
Fe-NC	0.1 M Na <sub>2</sub> SO <sub>4</sub>	0.50	137.9	10.5	30 h	45
MoSAs-Mo <sub>2</sub> C/NCNTs	0.005 M H <sub>2</sub> SO <sub>4</sub>	1.00	16.1	7.1	6 cycles	46
Ru SAs/N-C	0.05 M H <sub>2</sub> SO <sub>4</sub>	0.26	120.9	29.6	12 h	47
Au/TiO <sub>2</sub>	0.1 M HCl	1.00	21.4	8.1	10 cycles	48
GDY/Co <sub>2</sub> N	0.1 M Na <sub>2</sub> SO <sub>4</sub>	-	123.7	35.8	7 cycles	49
GDY/Co <sub>2</sub> N	0.1 M HCl	-	219.7	58.6	5 cycles	49

Au/Ti <sub>3</sub> C <sub>2</sub>	0.1 M HCl	0.003	30.1	18.3	15 h	50
Fe-ReS <sub>2</sub> @N-CNF	0.1 M Na <sub>2</sub> SO <sub>4</sub>	1.00	80.4	12.3	10 cycles	51
PC/Sb/SbPO <sub>4</sub>	0.1 M HCl	0.20	25.0	31.0	30 h	52
PdPb nanosponges	0.1 M HCl	0.20	25.7	5.8	10 h	53
Au flowers	0.1 M HCl	0.40	25.6	6.1	20 h	43
Au <sub>1</sub> /C <sub>3</sub> N <sub>4</sub>	0.005 H <sub>2</sub> SO <sub>4</sub>	0.89	1305	11.1	-	54
Mo-doped SnS <sub>2</sub>	0.5 M LiClO <sub>4</sub>	-	42.3	20.8	20 h	55
FL-BP NSs	0.5 M H <sub>2</sub> SO <sub>4</sub>	0.20	31.3	5.1	5 cycles	56

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