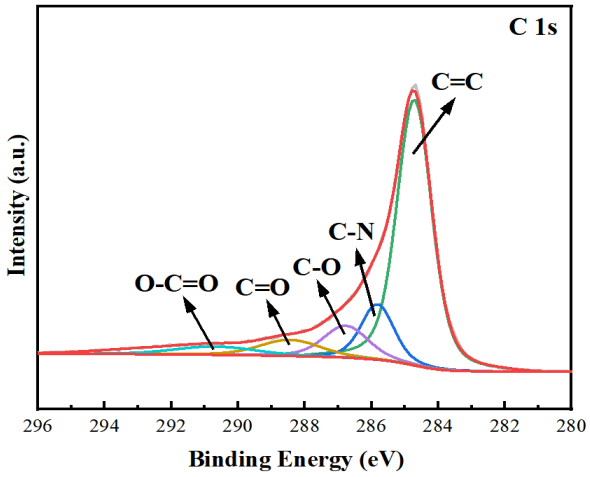

Figure S1. XPS of C 1s

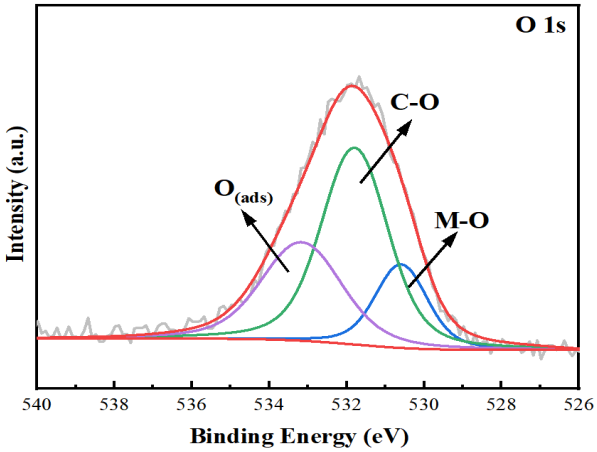

Figure S2. XPS of O 1s

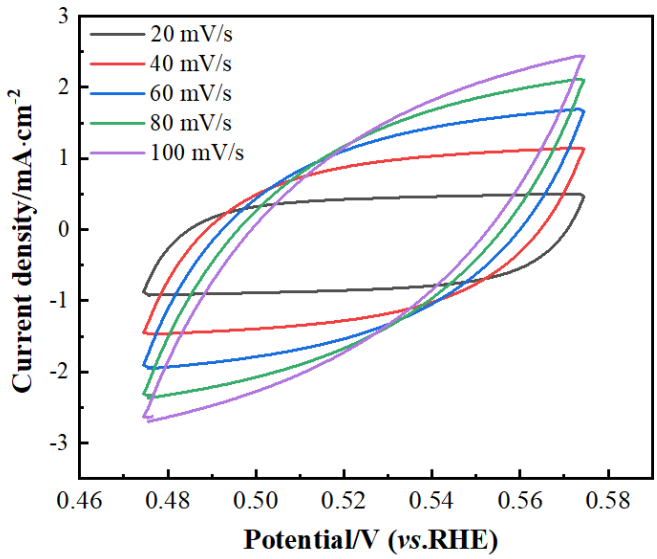

Figure S3. CV curves of CoNi/graphene at different sweep speeds in the range of 0.46V-0.58V

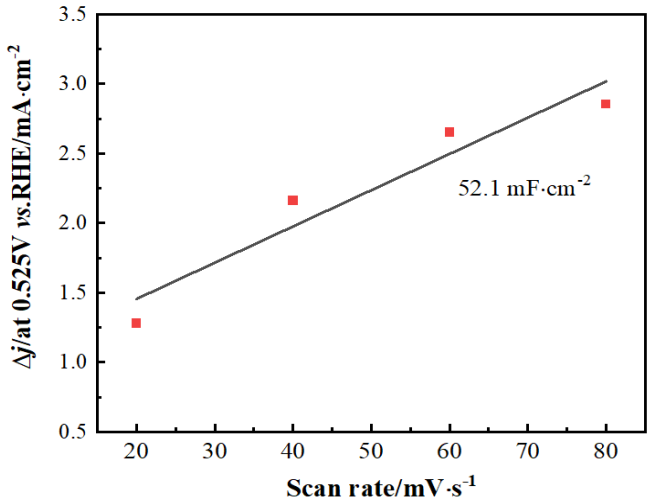

Figure S4. Based on the CV curve, the relationship between current density and sweep speed at 0.525V

Only Phen and only urea are added to the catalyst as reference catalysts, marked as CoNi-Phen-Graphene, CoNi-Urea-Graphene.

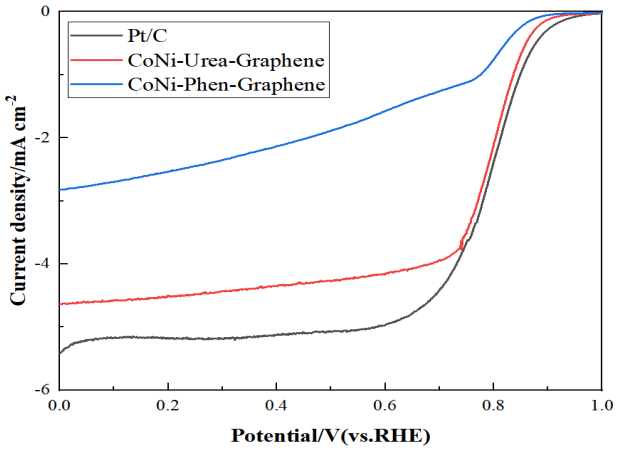

Figure S5. LSV curves of CoNi-Urea-Graphene, CoNi-Phen-Graphene and Pt/C for ORR recorded at 5.0 mV s^{-1} and 1600 rpm on RDE in O_2-saturated 0.1 mol L^{-1} KOH,

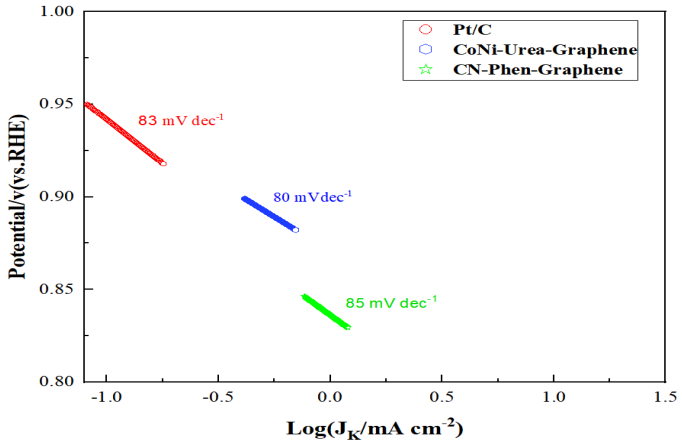

Figure S6. Corresponding Tafel plots

The number of electron transfer (n) of each O_2 molecule during ORR can be calculated by the slope of Koutecky–Levitch (K–L) as the following equation:

$$\frac{1}{j}=\frac{1}{j_L}+\frac{1}{j_k}=\frac{1}{B\omega^{1/2}}+\frac{1}{j_k}$$

$$B=0.2nFC_0D_0^{2/3}\nu^{-1/6}$$

where j is the measured current density, j_k is the kinetic kcurrent density, and j_L is the limiting diffusion current density. B is the Levitch constant, F is the Faraday constant (96485 C mol^{-1}), ω is the rotational speed (rpm), C_0 is the volume concentration of saturated oxygen in 0.1 M KOH (1.2 10^{-6} mol cm^{-3}), D_0 is the diffusion coefficient of

oxygen in the electrolyte solution (1.73 10^{-5} cm^2 s^{-1}), ν is the vis-cosity coefficient (0.01cm^2 s^{-1}) in the 0.1 M KOH electro-lyte solution, and n is the electron transfer number.

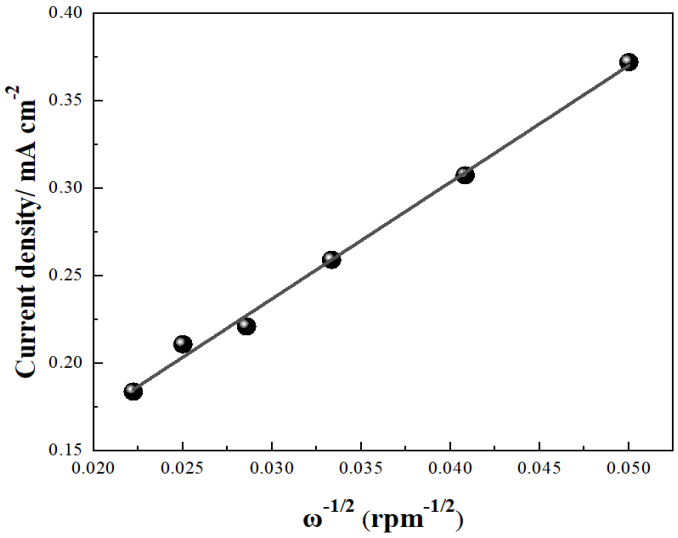

Figure S7. Electron transfer numbers (n) of ORR on the CoNi/graphene

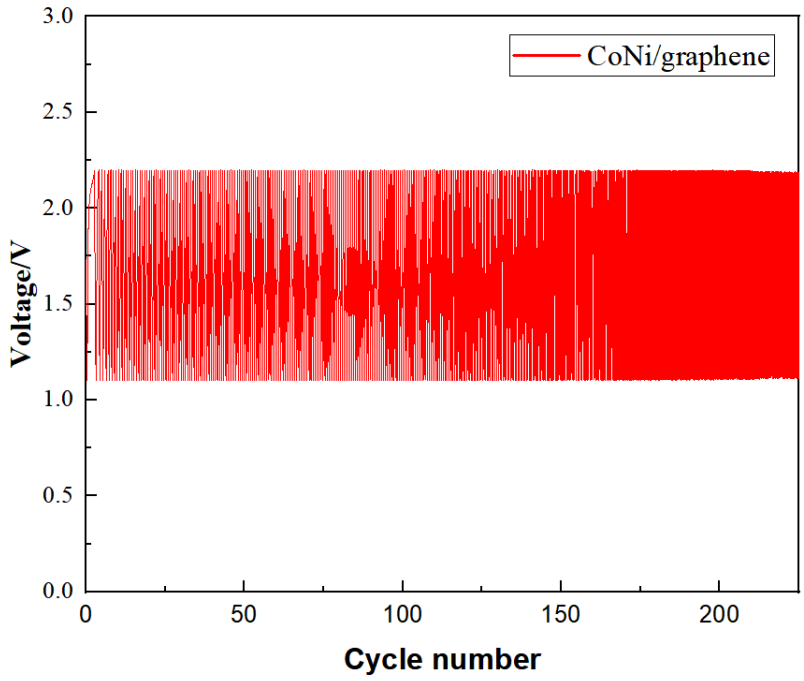

Figure S8. Galvanostatic discharge and charge cycling curves of SZABs with 15 min discharge and 15 min charge at 8 mA cm^{-2}

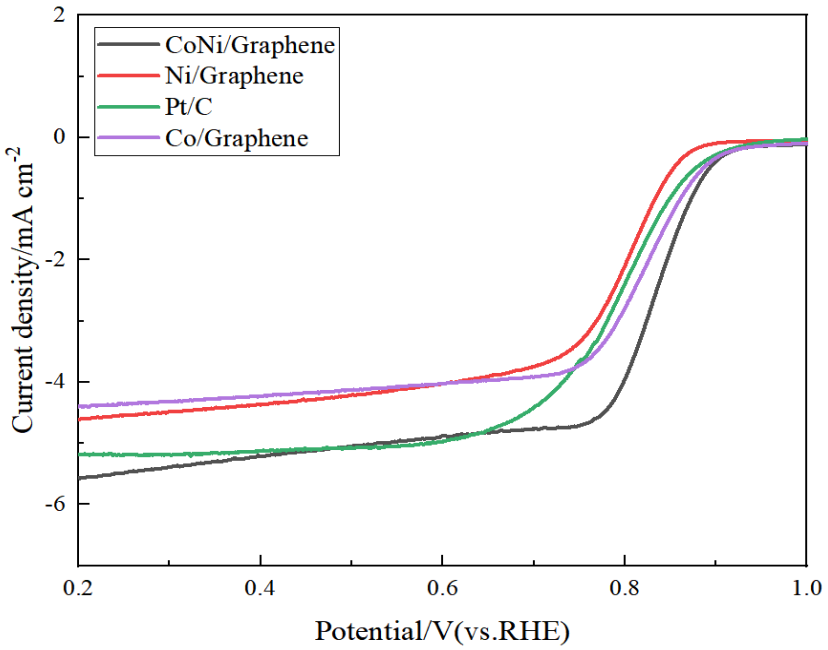

Figure S9. LSV curves of CoNi/Graphene, Co/Graphene,Ni/Graphene and Pt/C for ORR recorded at 5.0 mV s^{-1} and 1600 rpm on RDE in O_2-saturated 0.1 mol L^{-1} KOH

(In the contrast catalyst, only Co, Ni and CoNi were added, and the other nitrogen and carbon sources did not change.)

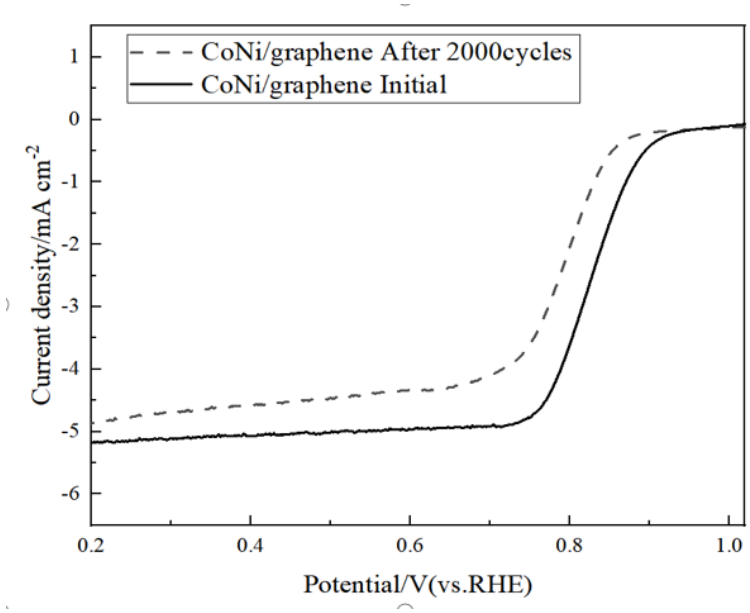

Figure S10. ORR polarization curves at 1600 rpm with a scan rate of 10 mV s^{-1} before and after 2000 cycles accelerated degradation test

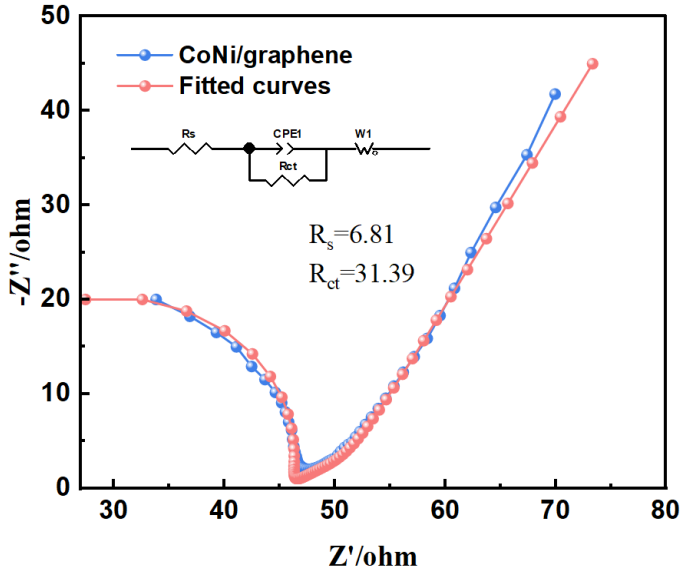

Figure S11. electrochemical impendence spectroscopy of CoNi/graphene

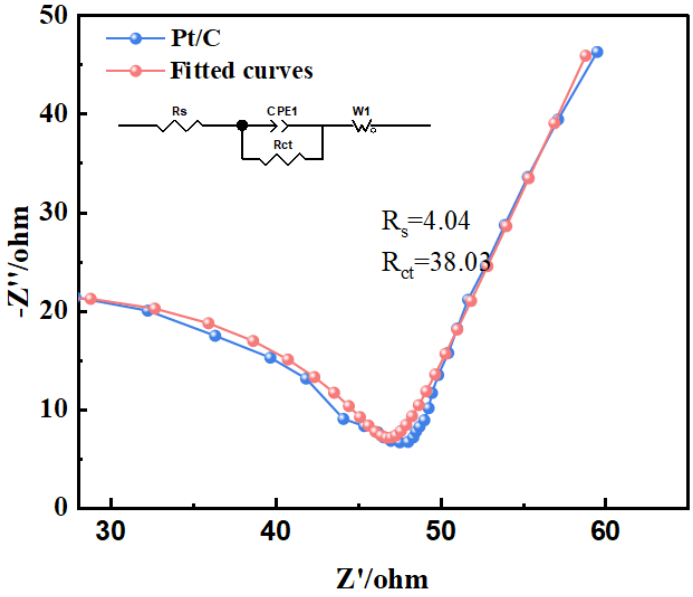

Figure S12. electrochemical impendence spectroscopy of Pt/C

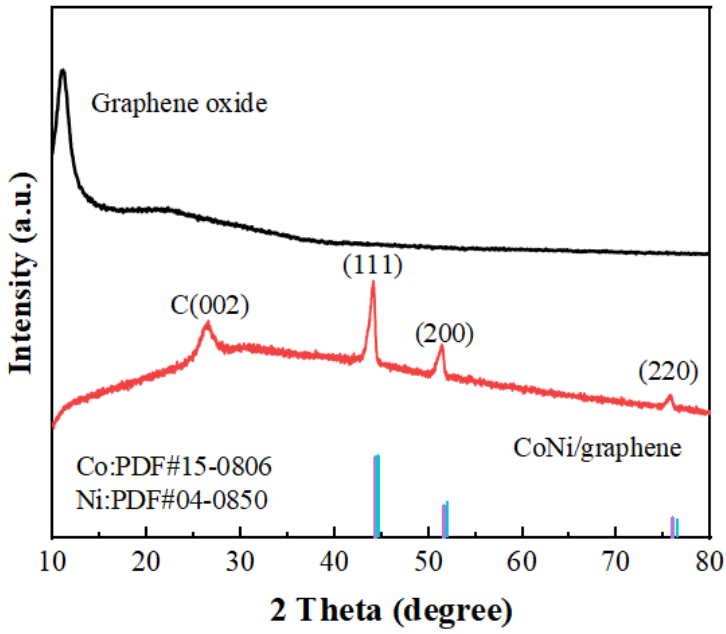

Figure S13. XRD patterns of Graphene oxide and CoNi/graphene

Table S1. Comparison of ORR performance for CoNi/graphene with other non-precious metal electrocatalysts in alkaline media

Catalyst	Electrolyte	Half-wave Potential (V vs. RHE)	LimitingCurrent Density @1600 rpm (mA cm^{-2})	Reference
N-doped carbon nanotube arrays	0.1 M KOH	0.84	5.6	Science 2009, 323, 760
Fe-N-C capsules	0.1 M KOH	0.83	4.9	ACS Nano 2016, 10, 5922
N-doped porous carbon fiber	0.1 M KOH	0.82	4.7	Adv. Mater. 2016, 28, 3000
N, S-doped Graphene sheets	0.1 M KOH	0.77	4.4	Nano Energy 2016, 19, 373

FeNi/N-LCN	0.1 M KOH	0.85	4.8	Nano Letter 2021, 21, 3105
N, S-doped porous carbo	0.1 M KOH	0.85	5.8	Energy Environ. Sci. 2017, 10, 742
CoNi-CoN_4-HPC-900	0.1 M KOH	0.78	7.1	Nano Energy 2022, 99, 107325
CoNi/graphene	0.1 M KOH	0.83	5.7	This Work

Table S2. Comparison of ORR performance for CoNi/graphene with other non-precious metal electrocatalysts in alkaline media

Catalyst	Electrolyte	Half-wave Potential (V vs. RHE)	Limiting current density @1600 rpm (mA cm^{-2})	Power density(m W cm^{-2})	Reference
Fe-N-C capsules	0.1 M KOH	0.83	4.9	125（liquid state）	ACS Nano 2016, 10, 5922
N-doped porous carbon fiber	0.1 M KOH	0.82	4.7	185（liquid state）	Adv. Mater. 2016, 28, 3000
N, S-doped Graphene sheets	0.1 M KOH	0.77	4.4	--	Nano Energy 2016, 19, 373
CoDNi-N/C	0.1 M KOH	0.84	5.5	--	Appl. Catal. B Environ. 2019,112–121
FeNi/N-LCN	0.1 M KOH	0.85	4.8	162（liquid state）	Nano Letter 2021, 21, 3105
Co/N@CNTs@CN	0.1 M	0.86	5.5	133	Adv. Funct.

MF	KOH			（liquid state ）	Mater. 2020, 2003407
CoNi-CoN_4-HPC-900	0.1 M KOH	0.78	7.1	--	Nano Energy 2022, 99, 107325
N-GQDs/NiCo2S4/ C	0.1 M KOH	--	--	26.2（solid state)	Small 2019, 15, 1903610
Co3O4@ LaNiO3/NCNT	0.1 M KOH	--	--	28.2（solid state)	Adv. Mater. 2015, 27, 5617
N@CNTs@C NM F	0.1 M KOH	--	--	26.5（solid state)	Adv. Funct. Mater. 2020, 30, 2003407
CoNi/graphene	0.1 M KOH	0.83	5.7	210（liquid state ）40（solid state）	This Work