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

Supporting Information

Smart Transformation of Worst Weed into N-, S-, and P-tridoped Carbon Nanorings as Metal-Free Electrocatalysts for Oxygen Reduction Reaction

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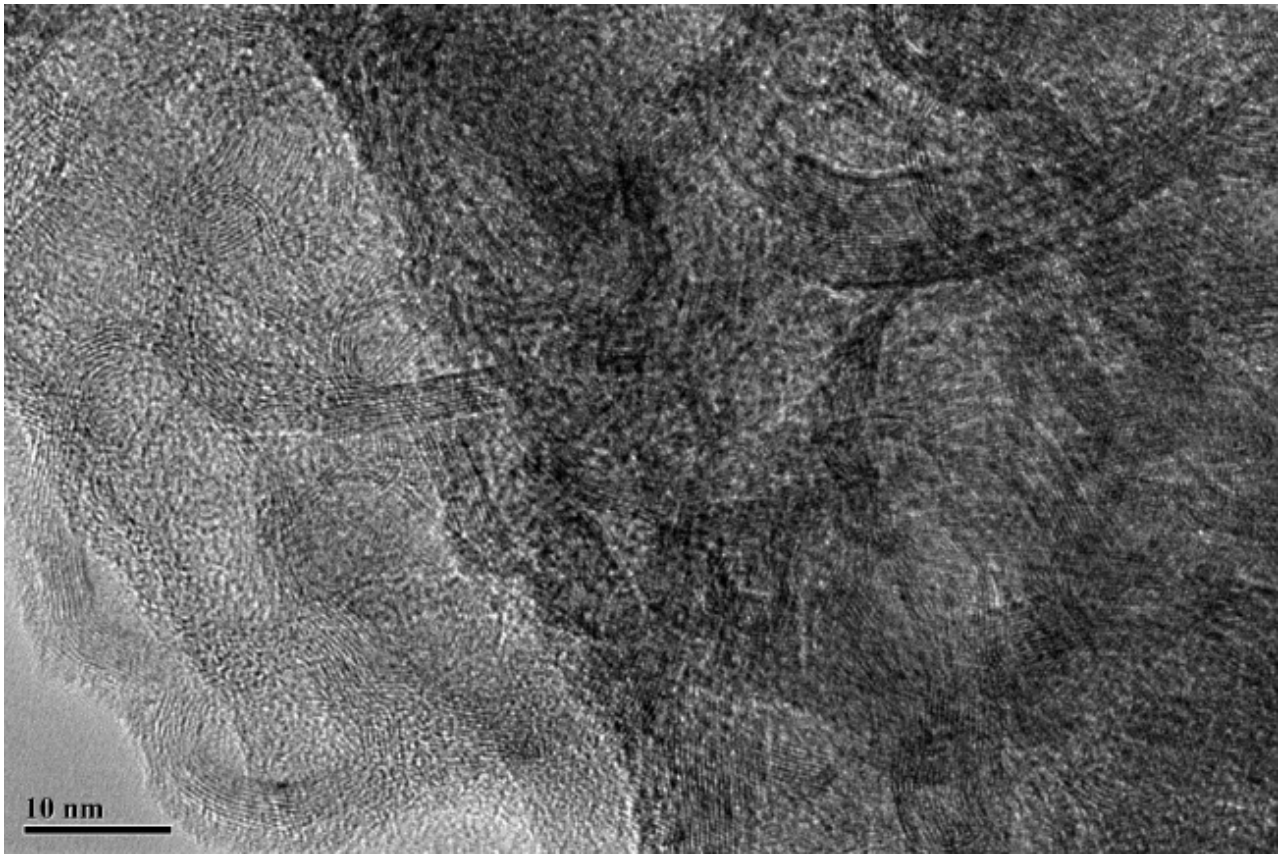

Figure S1. TEM image of WWCNRs.

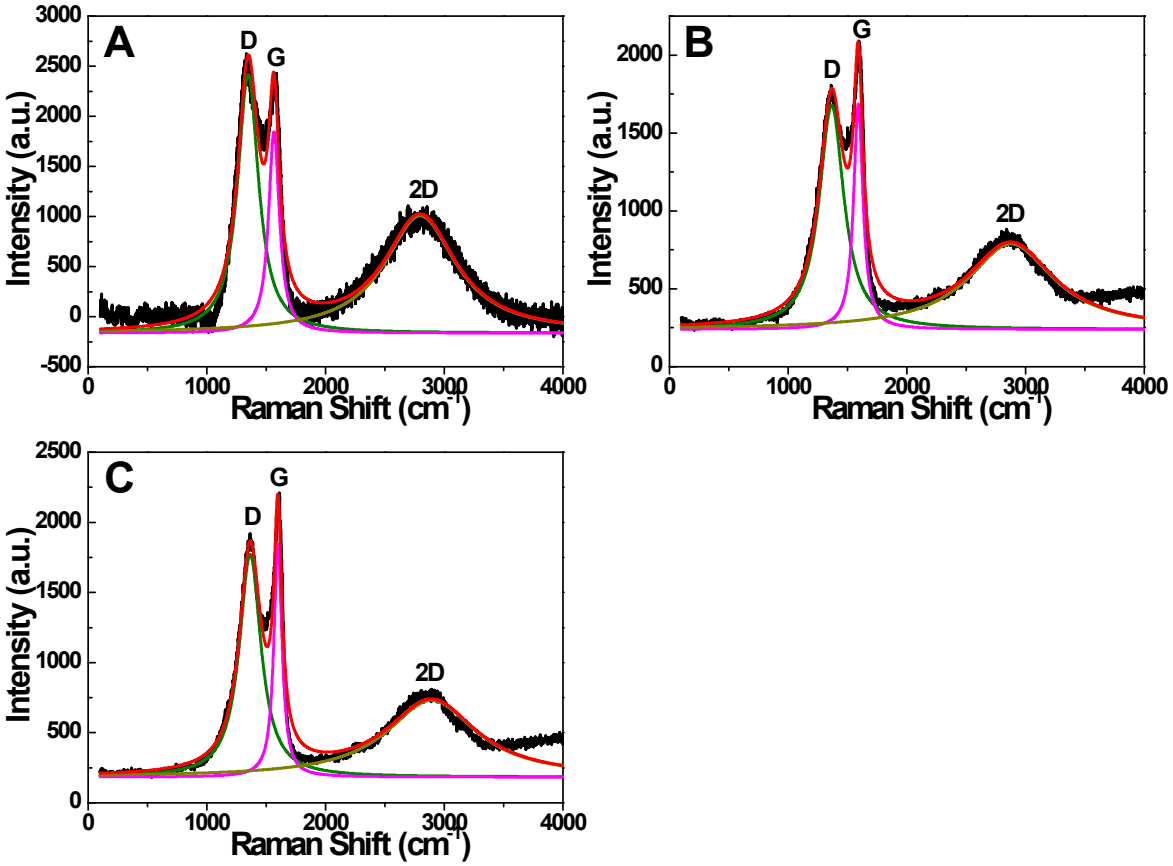

Figure S2. Ramanspectra of S-600 (A), S-700 (B), and S-900 (C) and their deconvolution into 3 bands.

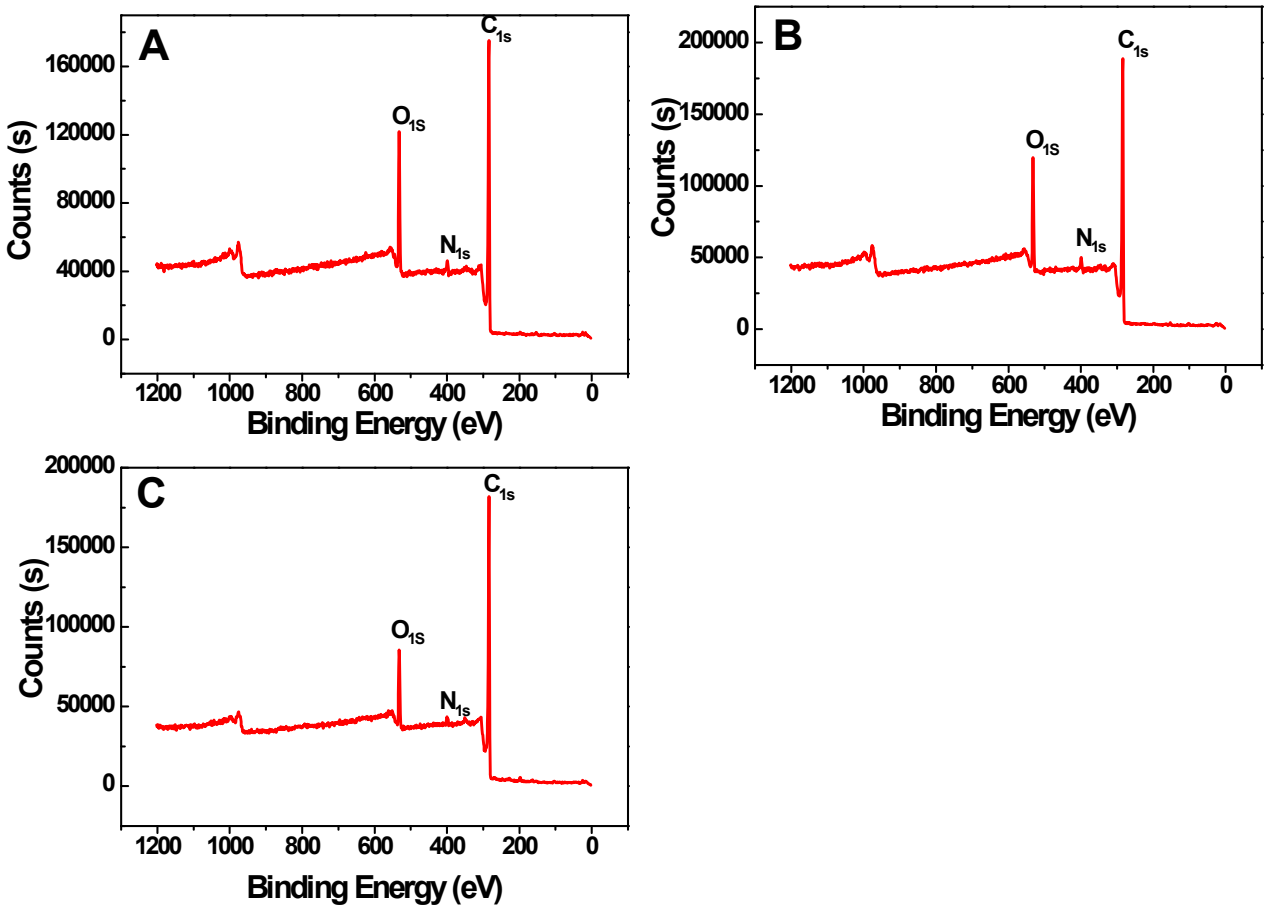

Figure S3. Full-scan XPS spectra of S-600 (A), S-700 (B), and S-900 (C).

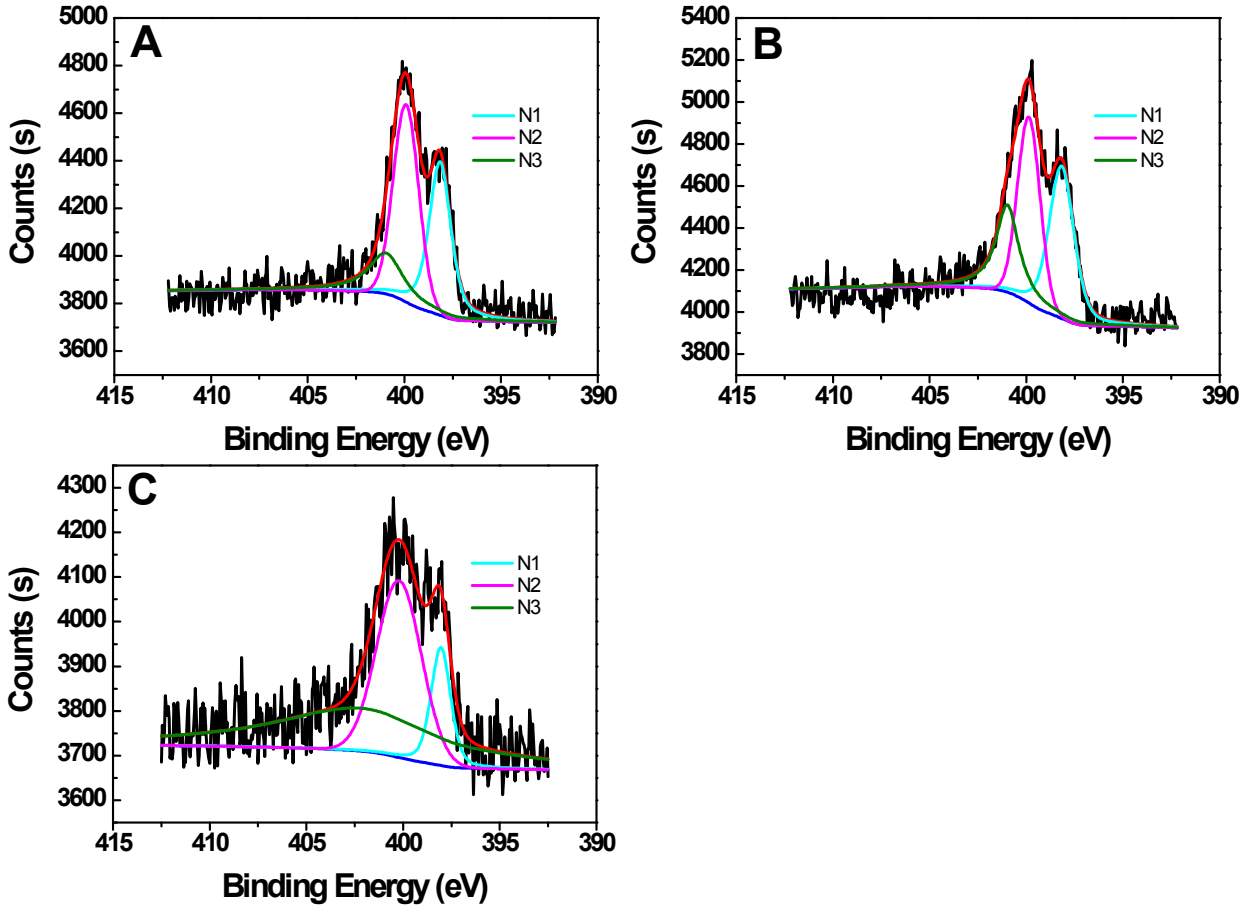

Figure S4. High resolution N1s XPS scan of S-600 (A), S-700 (B), and S-900 (C).

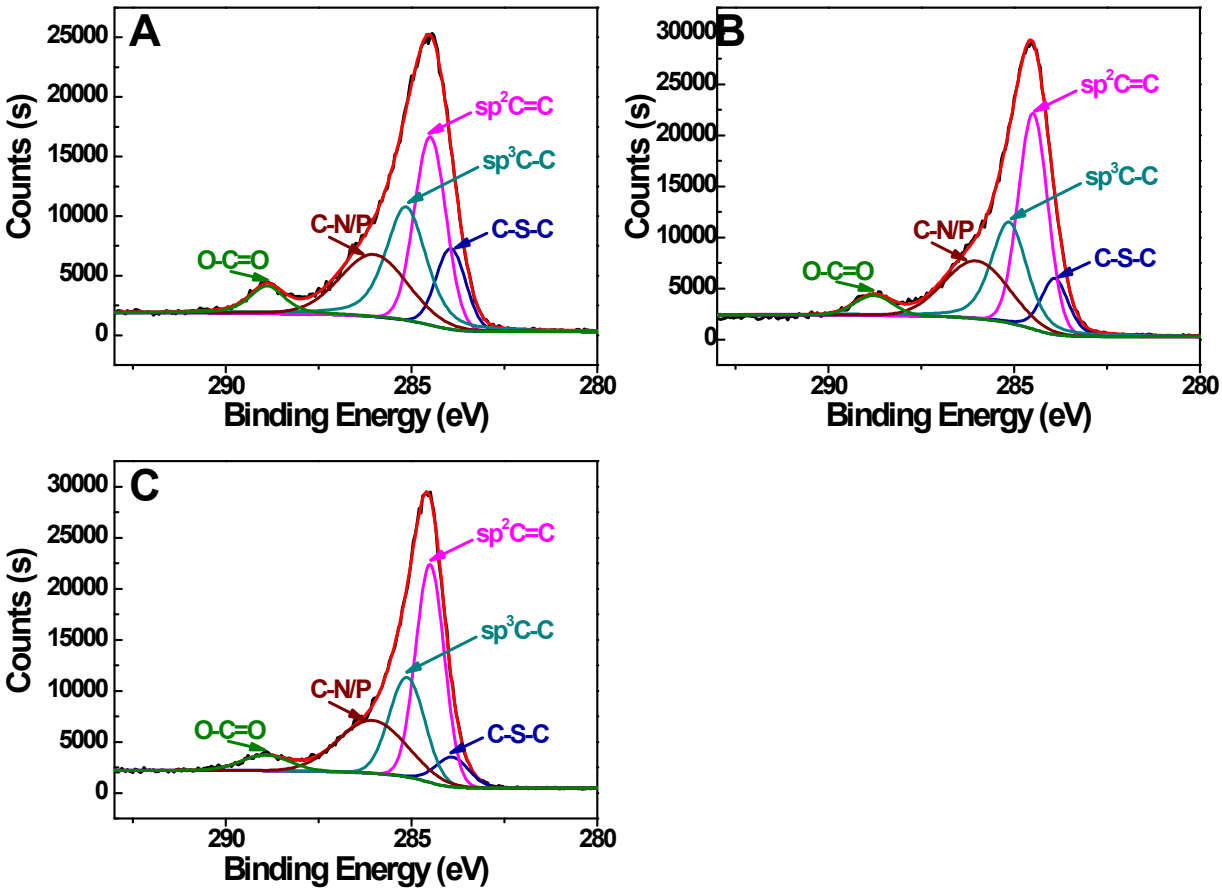

Figure S5. High resolution C1s XPS scans of S-600 (A), S-700 (B), and S-900 (C) and their deconvolution.

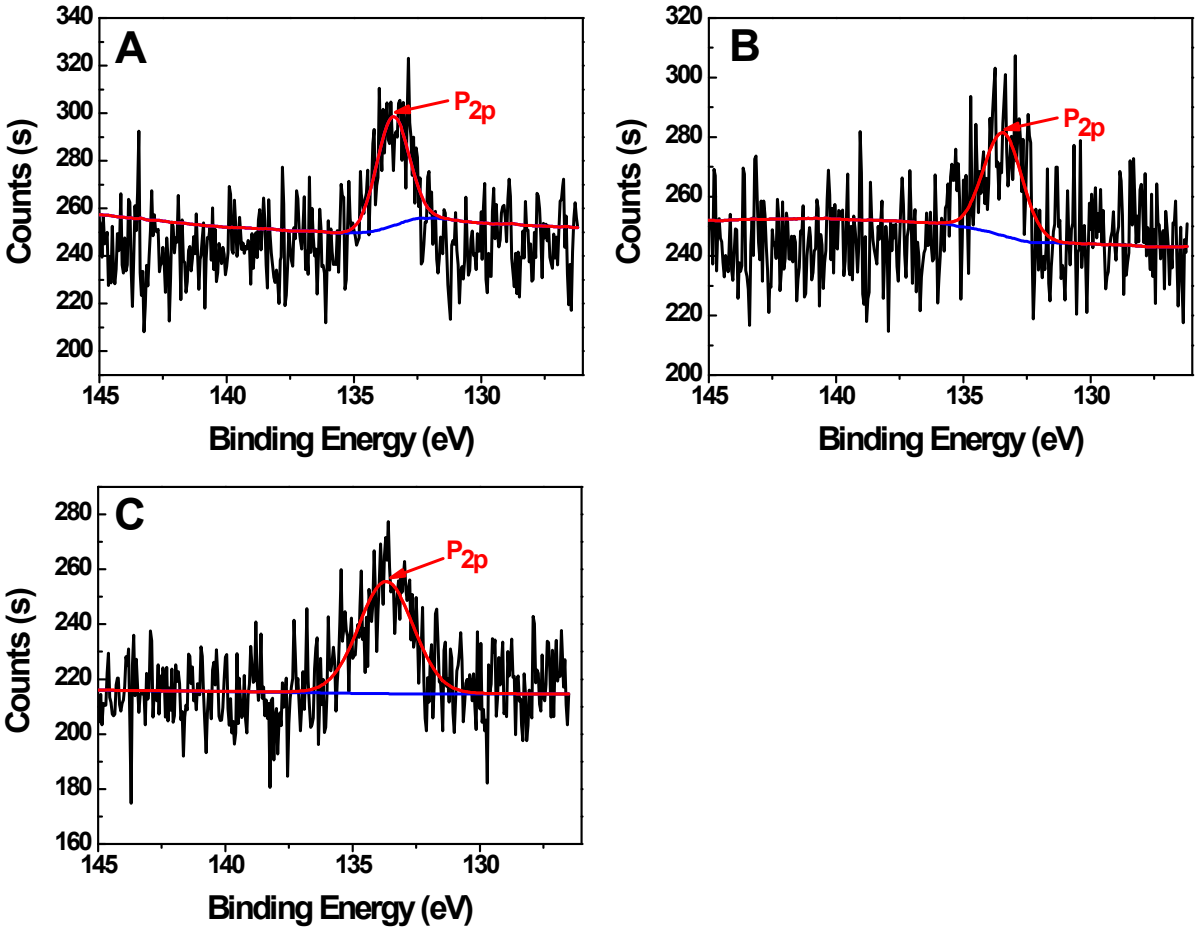

Figure S6. High resolution P2p XPS scan of S-600 (A), S-700 (B), and S-900 (C).

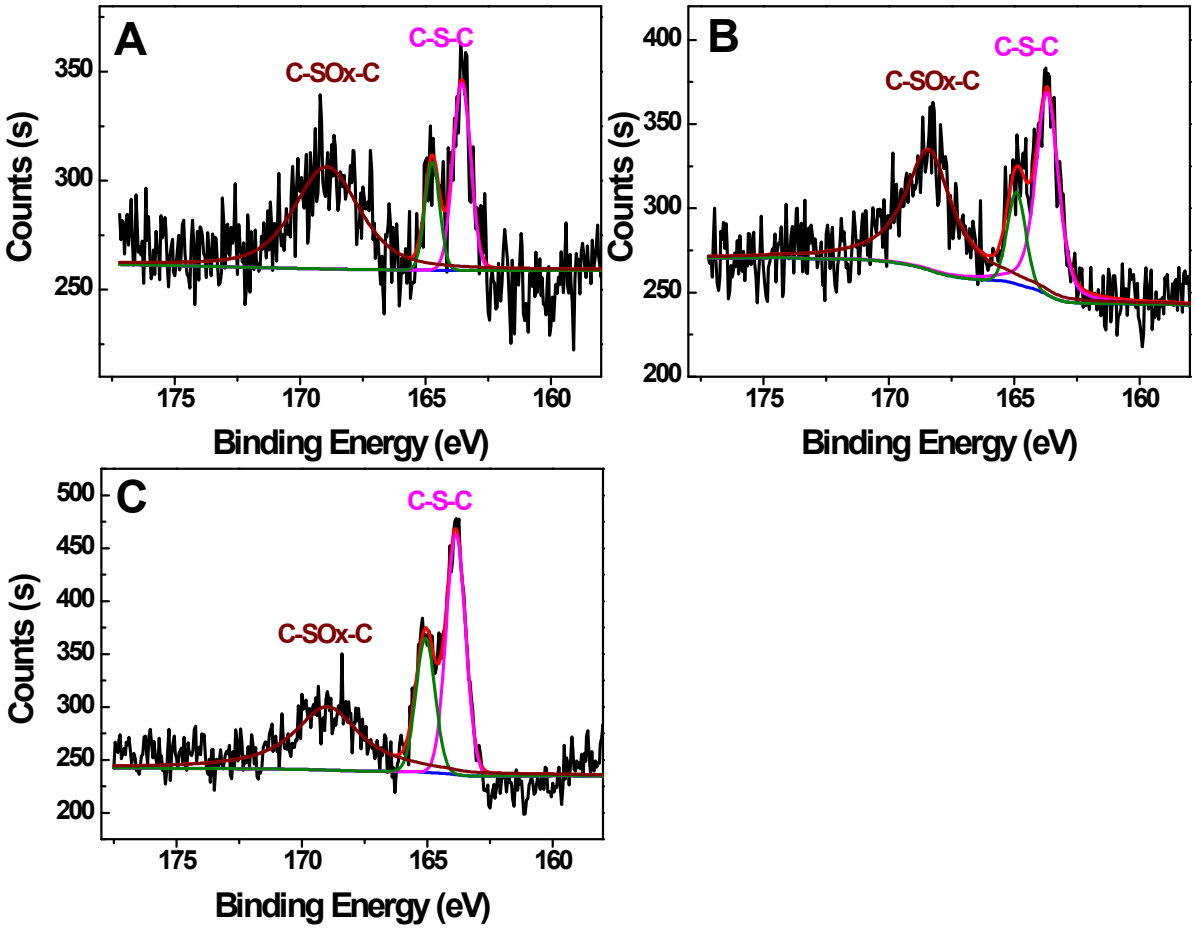

Figure S7. High resolution S2p XPS scan of S-600 (A), S-700 (B), and S-900 (C) and their deconvolution and assignment.

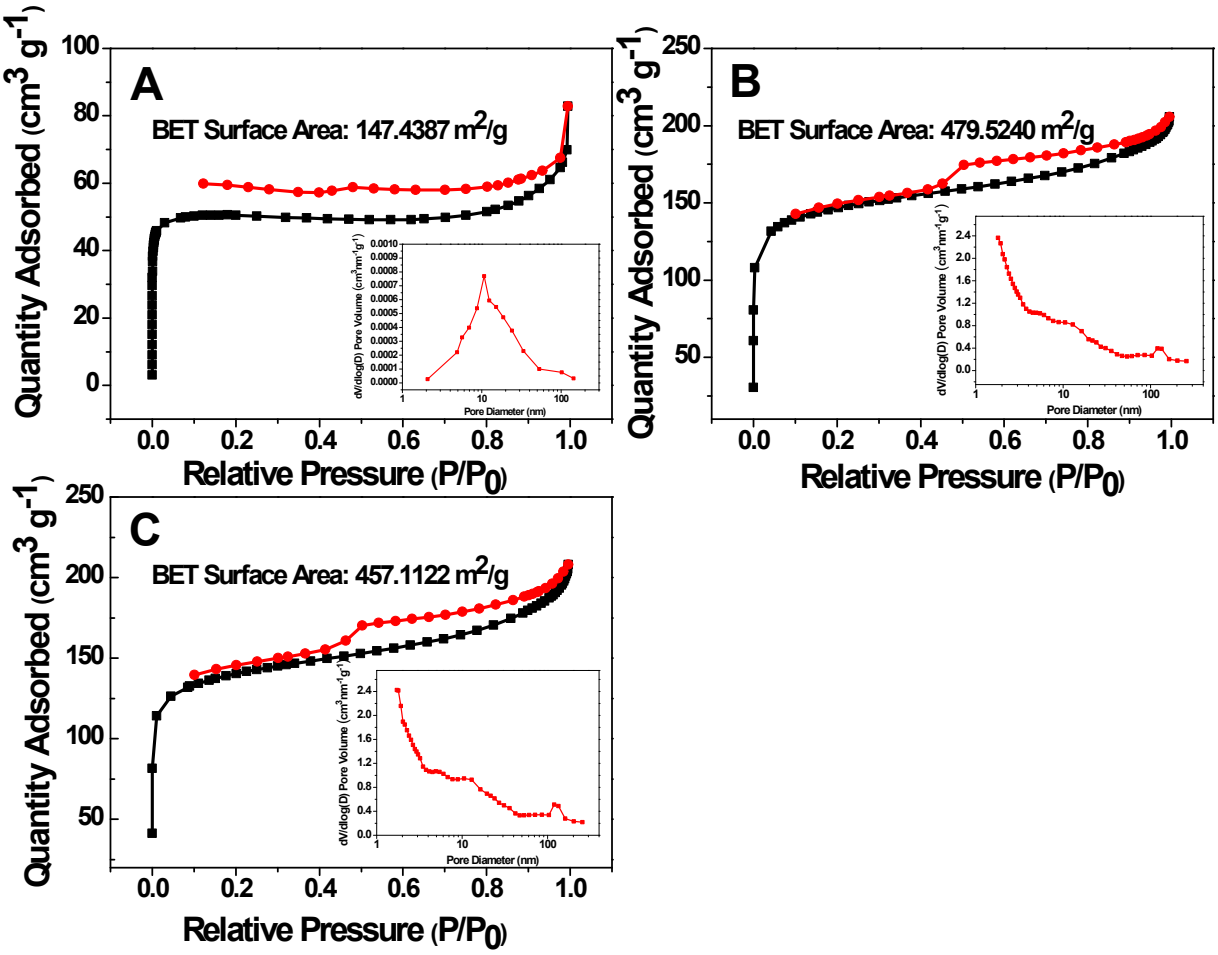

Figure S8. N2 adsorption–desorption isotherms of S-600 (A), S-700 (B), and S-900 (C). The inset is the corresponding pore-size distribution of S-600 (A), S-700 (B), and S-900 (C), respectively.

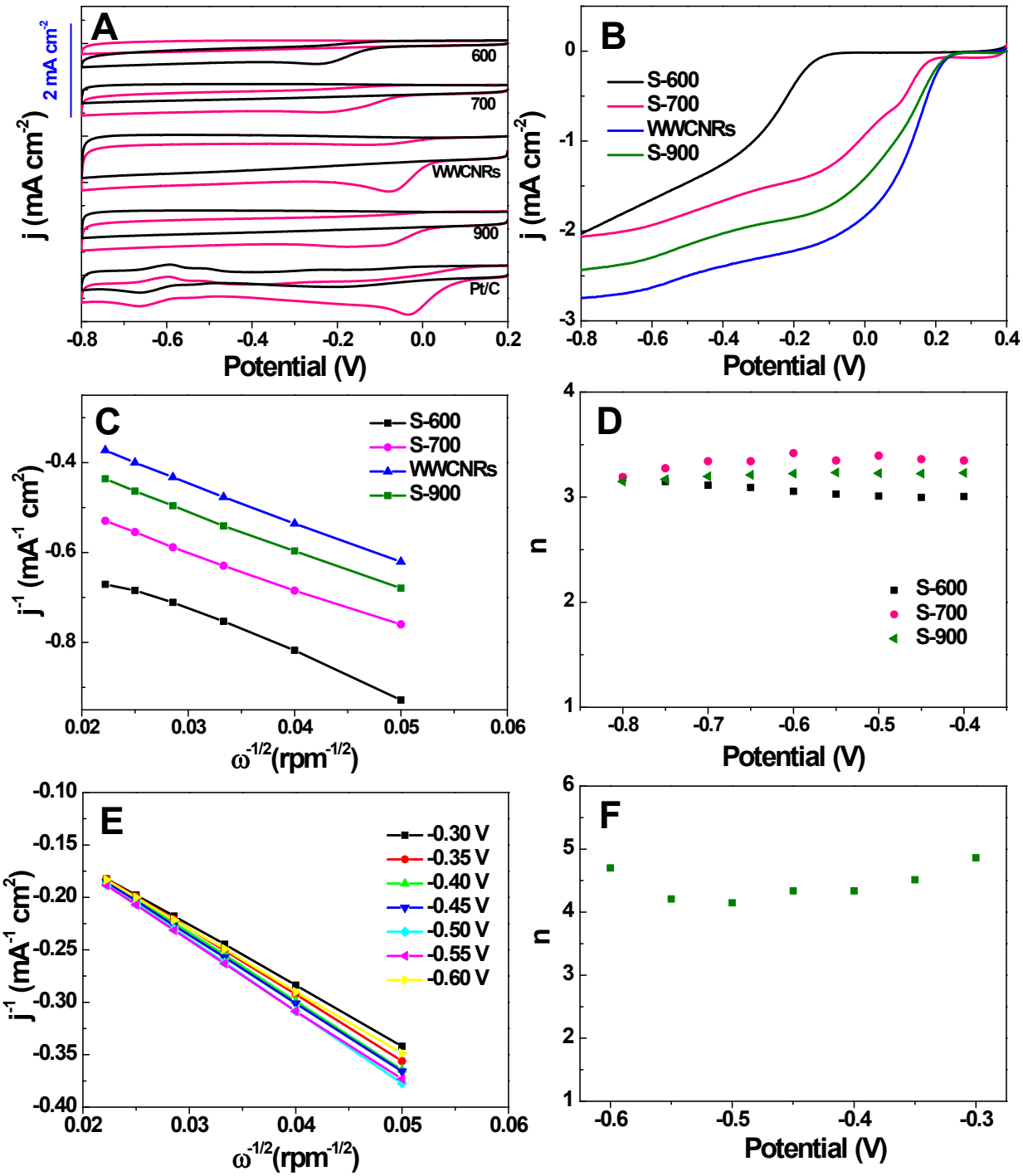

Figure S9. (A) CV curves of S-600, S-700, WWCNRs, S-900, and Pt/C in N_2-saturated, O_2-saturated 0.1 M KOH solution at a scan rate of 10 mV s^{-1}. (B) RDE curves for S-600, S-700, WWCNRs, S-900 in O_2-saturated 0.1 M KOH solution at a scanning rate of 10 mV s^{-1} at 1600 rpm.(C) K–L plots for the ORR in O_2-saturated 0.1 M KOH solution for S-600, S-700, WWCNRs, S-900at –0.5 V.(D) Electron numbers calculated from K–L plots. (E)K–L plots for the ORR in O_2-saturated 0.1 M KOH solution for Pt/C.(F) Electron numbers calculated from K–L plots for Pt/C.

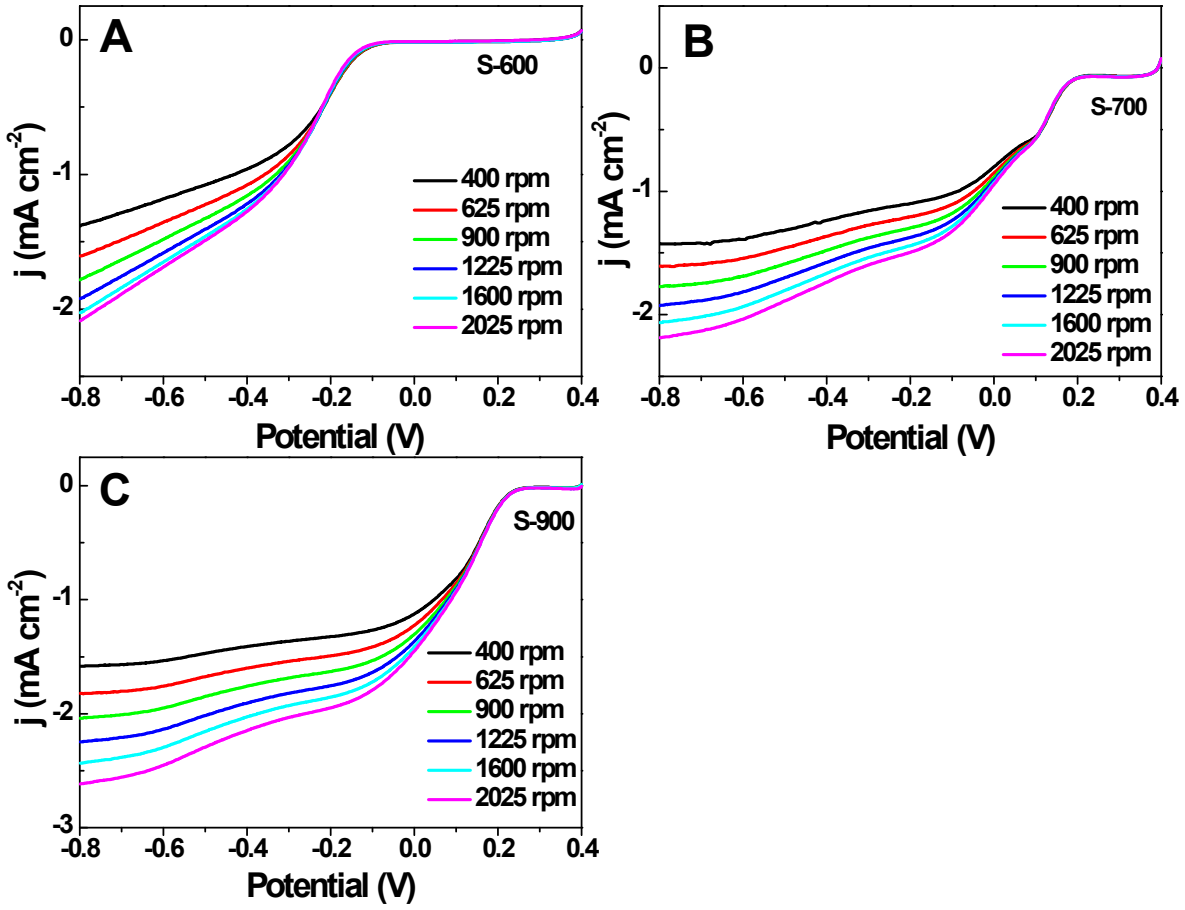

Figure S10. RDE curves for S-600 (A), S-700 (B), and S-900 (C) in 0.1 M KOH solution at a scanning rate of 10 mV s^{-1}at different rotation speeds.

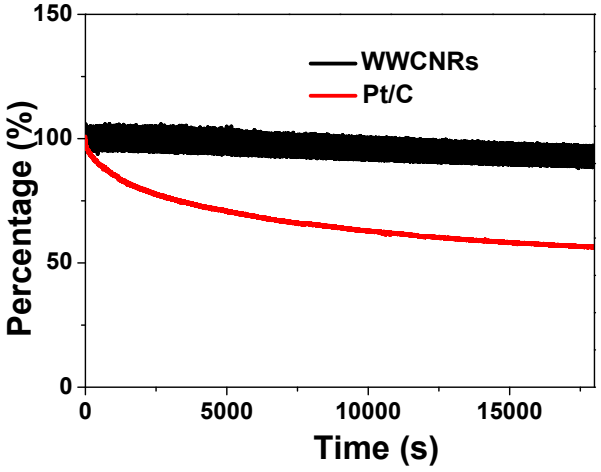

Figure S11. The comparison of the stability evaluation of WWCNRs with that of Pt/C reference catalyst for 18 000 s in an O_2-saturated 0.1 M KOH solution at −0.3 V.

Table S1. Summary of textural parameters obtained from nitrogen adsorption analysis and chemical composition analysis from XPS and electrochemical properties of the samples.

Sample	S_{BET} ($m^{-2}g^{-1}$)	Pore Volumes (cm^3g^{-1})	At% (C)	At% (N)	At% (O)	At% (P)	At% (S)	N1(%)	N2(%)	N3(%)	I_D/I_G	Onset Potential	Half-wave Potential
S-600	147.4387	0.0826	82.37	2.79	15.31	0.20	0.33	37	44	19	1.28	-0.16	-0.32
S-700	479.5240	0.3180	82.22	2.70	14.59	0.19	0.3	38	36	26	1	0.20	0.02
WWCNRs	378.5347	0.2676	82.14	1.50	15.67	0.21	0.49	38	34	28	0.99	0.25	0.11
S-900	457.1122	0.3218	87.37	1.34	10.57	0.17	0.55	12	36	52	0.95	0.24	0.08

Table S2. Comparison of experimental conditions and ORR activities and kinetics of heteroatom-doped nanocarbon catalysts.

Catalyst	Electrolyte	Reference electrode a	Onset Potential (V vs RHE) [b]	Half wave Potential (V vs RHE) [b]	Kinetic current at 0.7 V vs RHE (mA cm $^{-2}$) [c]	Reference
WWCNRs	**0.1 M KOH**	**Hg/HgO**	**1.13**	**0.99**	**4.88(@ 0.5 V)**	**This study**
N-S-HC850	0.1 M KOH	Ag/AgCl	0.89	0.78	N/A	[1]
PAC/5S	0.1 M KOH	RHE	0.86	0.75	4.25	[2]
GC-NLS	0.1 M KOH	RHE	0.85	0.72	N/A	[3]
NPC-0	0.1 M KOH	RHE	0.82	0.73	4.16(@ 0.3 V)	[4]
N/S-GFs	0.1 M KOH	Ag/AgCl	0.73	0.65	N/A	[5]
CNT/HDC-1000	0.1 M KOH	RHE	0.92	0.82	8.3	[6]
CNT@NPC-900	0.1 M KOH	Ag/AgCl	0.80	0.73	N/A	[7]
NGR-900	0.1 M KOH	Ag/AgCl	0.81	0.72	N/A	[8]
CPGA-600	0.1 M KOH	SCE	0.93	N/A	N/A	[9]
N-CC@CNTs	0.1 M KOH	RHE	1.01	0.88	N/A	[10]
N-PCs-700	0.1 M KOH	Ag/AgCl	0.88	N/A	N/A	[11]
N-CSs-800	0.1 M KOH	Hg/HgO	0.82	0.76	2.86	[12]
N-CSs	0.1 M KOH	Ag/AgCl	0.82	0.67	N/A	[13]
BCN graphene	0.1 M KOH	SCE	N/A	0.67	N/A	[14]
S-PGHS	0.1 M KOH	Ag/AgCl	0.81	N/A	N/A	[15]
N-GQDs	0.1 M KOH	Ag/AgCl	0.67	0.55	N/A	[16]
HNCS 71	0.1 M KOH	RHE	0.87	0.82	N/A	[17]
B, N-GQD/G-	0.1 M KOH	Ag/AgCl	0.91	N/A	N/A	[18]
B, N-Graphene	0.1 M KOH	Ag/AgCl	N/A	0.65	0.26	[19]
S1-AZ-800	0.1 M KOH	Hg/HgO	0.90	0.73	3.13	[20]
NSG700	0.1 M KOH	SCE	0.84	N/A	N/A	[21]
N-Porous Carbons	0.1 M KOH	RHE	0.86	0.70	N/A	[22]
N 550-GD	0.1 M KOH	Ag/AgCl	0.90	N/A	N/A	[23]
N , O-OMC	0.1 M KOH	RHE	0.71	0.68	0.48	[24]
NPM	0.1 M KOH	RHE	0.85	0.69	N/A	[25]
Macroporous C_3N_4@Carbon	0.1 M KOH	Ag/AgCl	N/A	0.62	1.3	[26]
Mesoporous N-Carbon	0.1 M KOH	Ag/AgCl	0.90	0.79	5.4	[27]
N-Carbon Nanocage	0.1 M KOH	Ag/AgCl	0.79	0.65	1.6	[28]
N-Hollow Carbon NP	0.1 M KOH	Ag/AgCl	0.84	0.67	0.05	[29]
N-CDs	0.1 M KOH	Hg/HgO	0.88	0.64	N/A	[30]

[a)]Conversions of Hg/HgO electrode, Ag/AgCl electrode, and SCE into RHE scale were achieved by adopting the calibration results;[b)]Half-wave potential was obtained from linear sweep voltammetry unless otherwise noted.

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