Electronic Supplementary Material (ESI) for Catalysis Science & Technology.

Supporting Information

Highly dispersed Co-N-RGO electrocatalyst based on interconnected-hierarchical pore framework for Proton exchange membrane fuel cell

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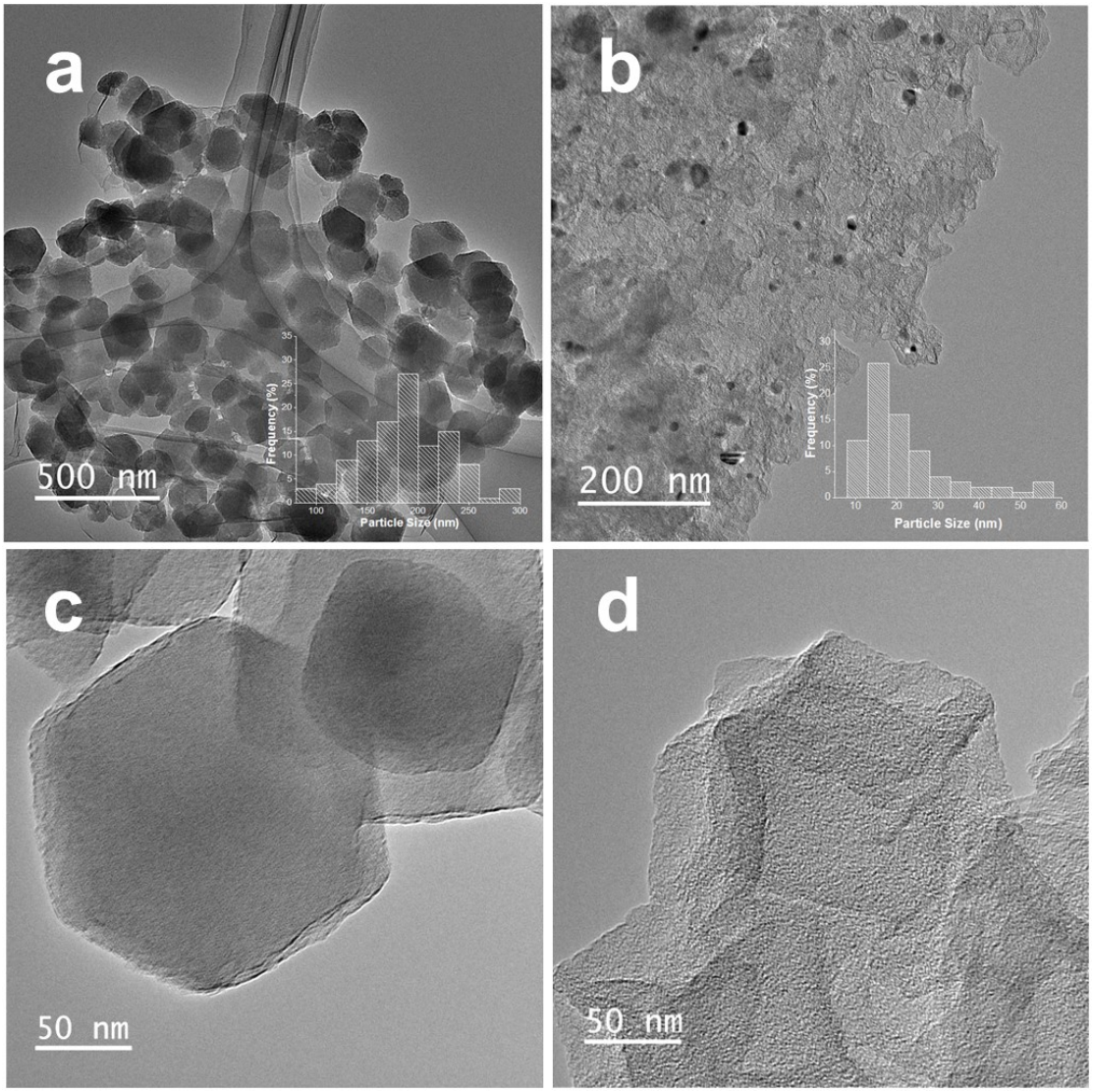

Fig.S1 TEM images of (a) precursor of Co-N-RGO-1.5, (b) Co-N-RGO-3, (c) precursor of Co-N-RGO-1.5, (d) Co-N-RGO-1.5. The inserted histogram in (a, b) is the corresponding statistics of particle size distribution.

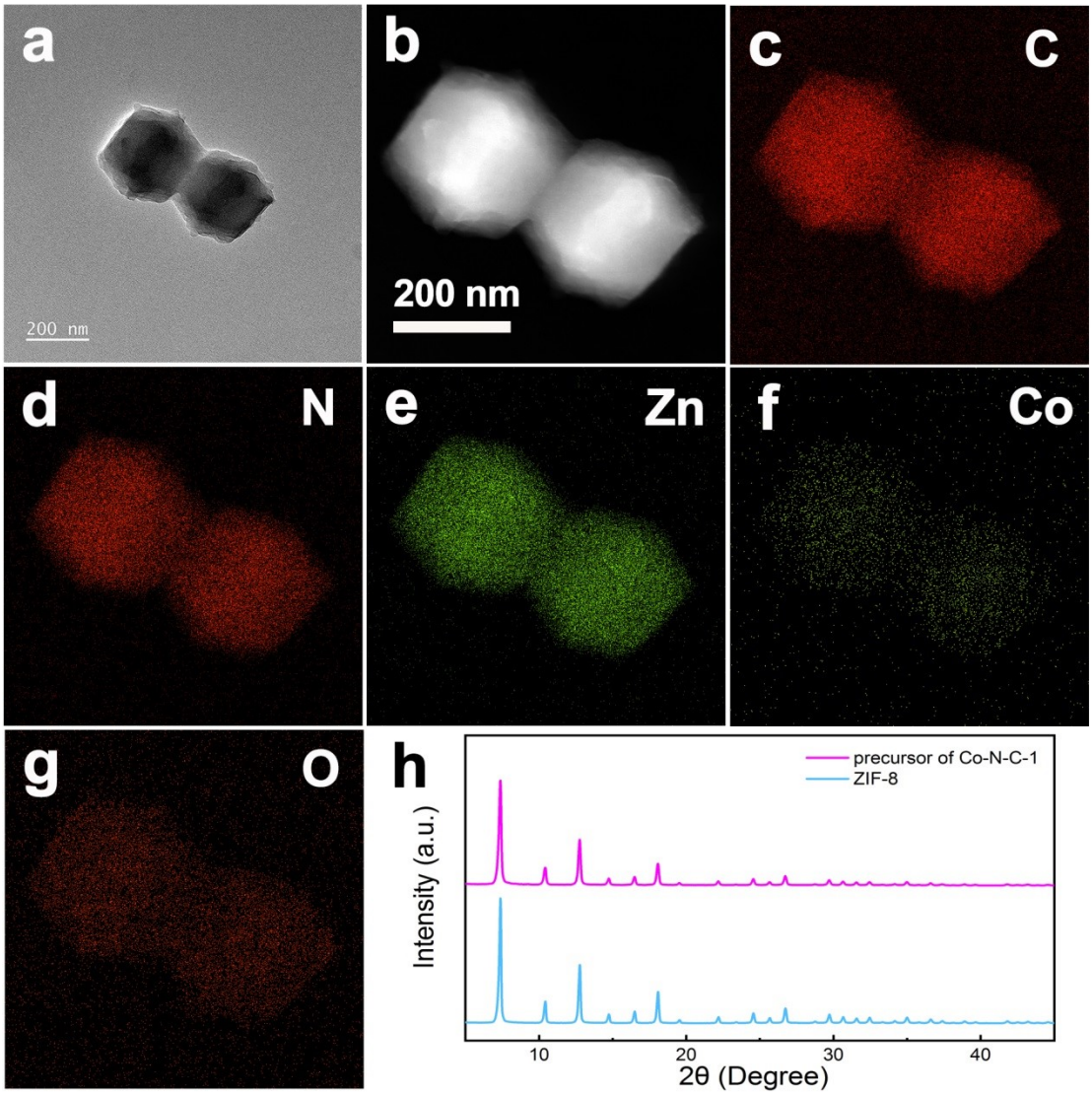

Fig. S2 (a) TEM and (b) STEM images of the precursor of Co-N-C-1. Elemental mappings of (c) C, (d) N, (e) Zn, (f) Co and (g) O of the area in (b). (h) XRD patterns of ZIF-8 and the precursor of Co-N-C-1.

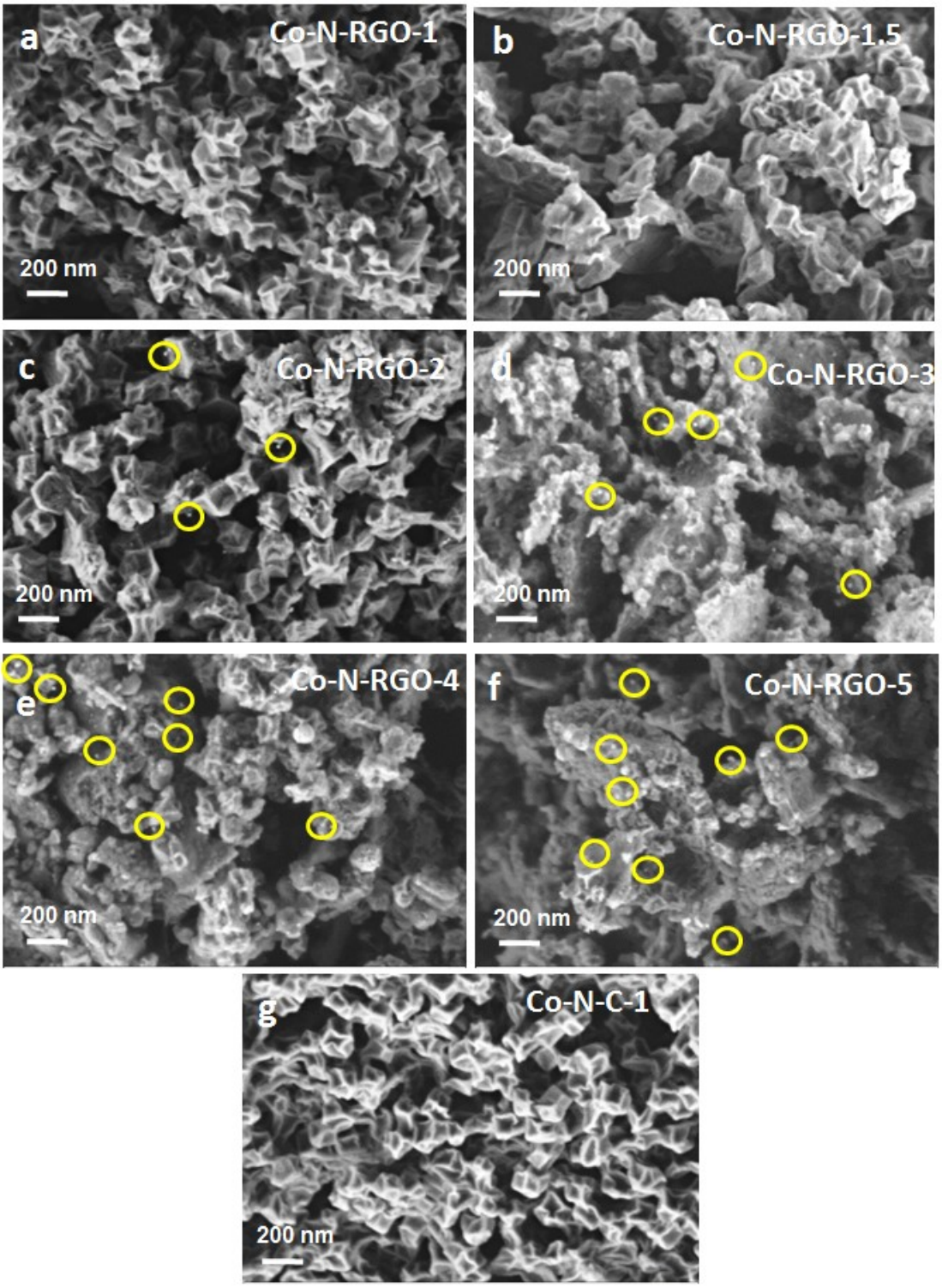

Fig. S3 SEM images of synthesized samples

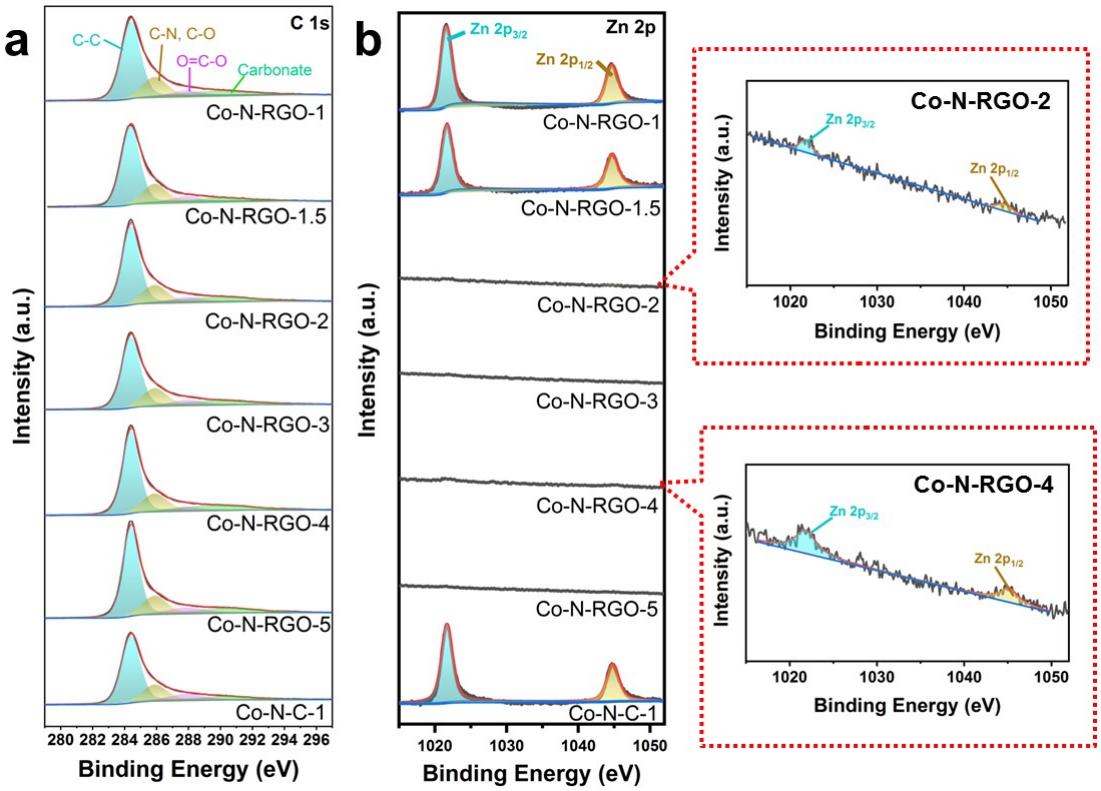

Fig. S4 High-resolution XPS data of (a) C 1s and (b) Zn 2p

Table S1 Relative contents of various C species in samples.

Sample	C-C (at.%)	C-N & C-O (at.%)	O=C-O (at.%)	Carbonate (at.%)	total C content (at.%)
Co-N-RGO-1	62.9	19.6	5.7	11.8	85.52
Co-N-RGO-1.5	67.5	19.3	6.0	7.2	84.24
Co-N-RGO-2	63.3	18.4	5.4	12.8	86.58
Co-N-RGO-3	62.0	19.2	6.5	12.3	83.43
Co-N-RGO-4	62.9	18.9	3.7	14.5	88.64
Co-N-RGO-5	63.5	18.0	7.6	10.9	89.83
Co-N-C-1	63.0	18.9	9.5	8.6	85.38

Table S2 Relative contents of various N species in samples.

Sample	pyridinic N (at.%)	Co-N_X (at.%)	pyrrolic-N (at.%)	graphitic N (at.%)	oxidized N (at.%)	total N content (at.%)
Co-N-RGO-1	51.7	10.8	20.2	6.7	10.6	8.97
Co-N-RGO-1.5	47.3	15.2	17.0	10.2	10.2	8.31
Co-N-RGO-2	36.6	17.3	21.9	12.4	11.9	5.70
Co-N-RGO-3	37.7	19.2	16.6	15.1	11.3	7.73
Co-N-RGO-4	29.2	15.7	19.1	23.2	12.8	4.78
Co-N-RGO-5	28.5	15.6	19.2	24.9	11.8	4.07
Co-N-C-1	42.9	6.4	31.9	10.0	8.9	6.92

Table S3 Relative contents of various Co species in samples.

Sample	Metallic Co (at.%)	Co_x-O_y (at.%)	Co-N_X (at.%)	Satellite (at.%)	total Co content (at.%)
Co-N-RGO-1	5.1	37.9	36.6	20.4	0.49
Co-N-RGO-1.5	5.3	34.8	34.7	25.2	0.64
Co-N-RGO-2	5.8	36.1	25.7	32.4	1.28
Co-N-RGO-3	8.4	28.9	29.8	32.9	1.73
Co-N-RGO-4	11.8	34.0	32.5	21.8	1.30
Co-N-RGO-5	13.2	31.5	25.4	29.9	1.11
Co-N-C-1	5.8	29.3	28.3	36.6	0.55

Table S4 Relative contents of Zn species in samples.

Sample	total Zn content (at.%)
Co-N-RGO-1	0.69
Co-N-RGO-1.5	0.62
Co-N-RGO-2	0.01
Co-N-RGO-3	0.01
Co-N-RGO-4	0.02
Co-N-RGO-5	0.01
Co-N-C-1	0.67
precursor of Co-N-C-1	9.38

Fig. S5 The contact angle tests between deionized water and the catalyst layer of Co-N-RGO-1.5 sample

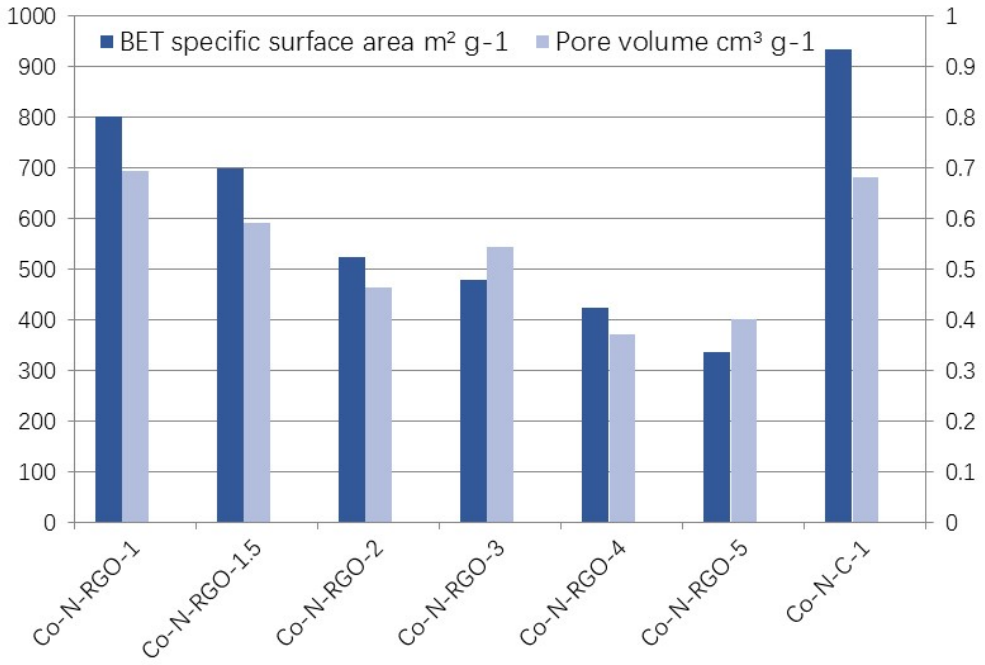

Fig. S6 BET specific surface area and pore volume distribution

Table S5 Specific surface area and pore volume distribution of samples.

Sample	S_{BET} $m^2\ g^{-1}$	Pore volume $cm^3\ g^{-1}$	$V_{micrpores}$ $cm^3\ g^{-1}$	$V_{mespores\ \&\ macrpores}$ $cm^3\ g^{-1}$
Co-N-RGO-1	**802.0443**	**0.693864**	**0.367557**	**0.326307**
Co-N-RGO-1.5	**699.0128**	**0.591648**	**0.310218**	**0.281430**
Co-N-RGO-2	**522.6528**	**0.463547**	**0.240491**	**0.223056**
Co-N-RGO-3	**478.5023**	**0.543165**	**0.218958**	**0.324207**
Co-N-RGO-4	**424.7778**	**0.370319**	**0.190819**	**0.179500**
Co-N-RGO-5	**335.5853**	**0.400661**	**0.151920**	**0.248741**
Co-N-C-1	**934.4712**	**0.680550**	**0.463552**	**0.216998**

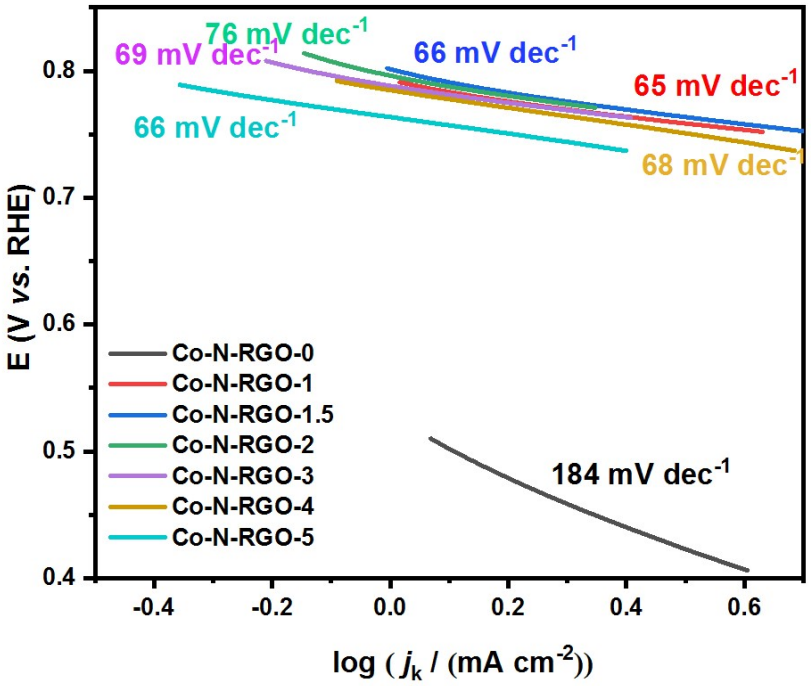

Fig. S7 Tafel slope of synthesized catalysts

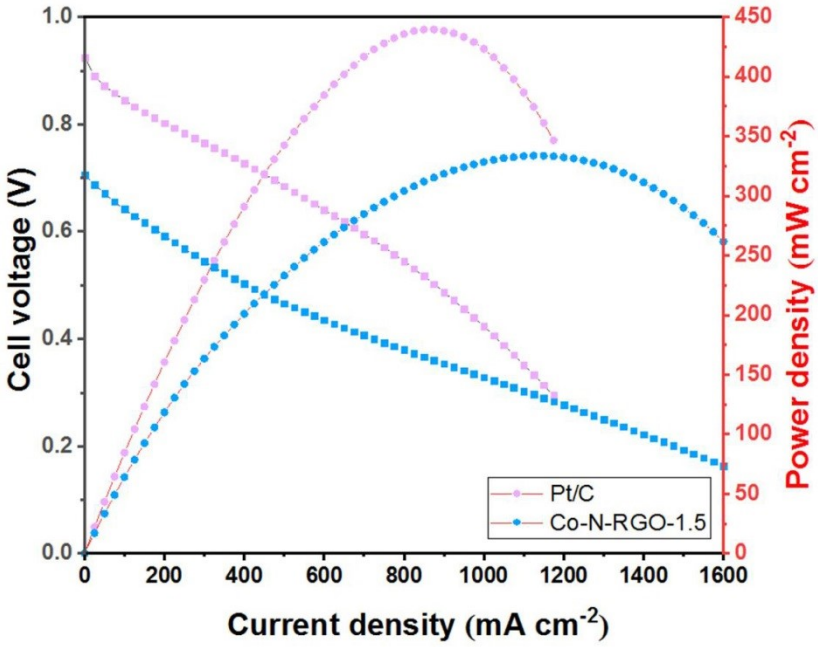

Fig. S8 The performance of Co-N-RGO-1.5 and commercial Pt/C fuel cell

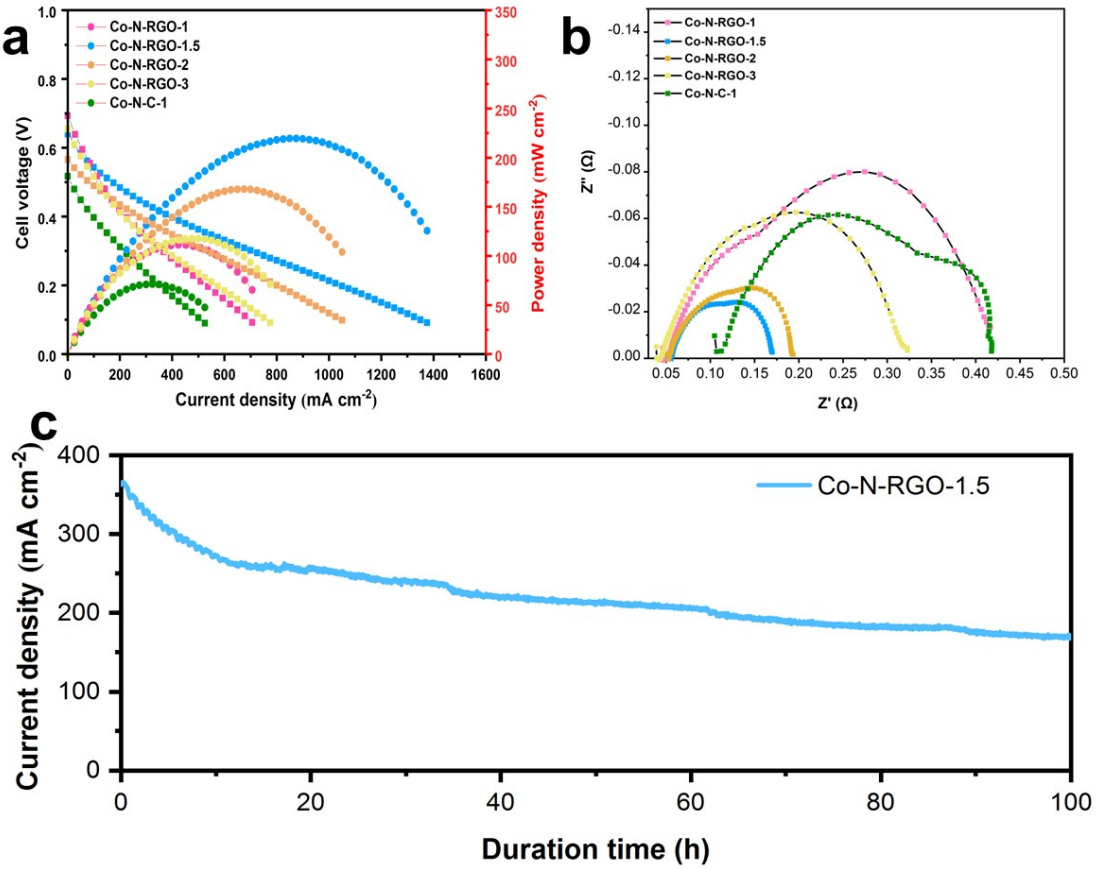

Fig. S9 (a)The performance and (b)EIS image of fuel cells after 24-hour stability test. (c) The variation of current density of H_2/O_2 PEMFC with Co-N-RGO-1.5 catalyst as the cathode at 0.5 V for 100 hours. Testing conditions: 1 bar backpressures; Flow rate: 200 sccm for both H_2 and O_2, humidified at 80°C; MEA active area: 2.01 cm^2; Nafion 211 membrane; Cathode loading: 4.0 mg cm^{-2}; Anode catalyst: Pt/C with loading of 0.5 mg_{pt} cm^{-2}.

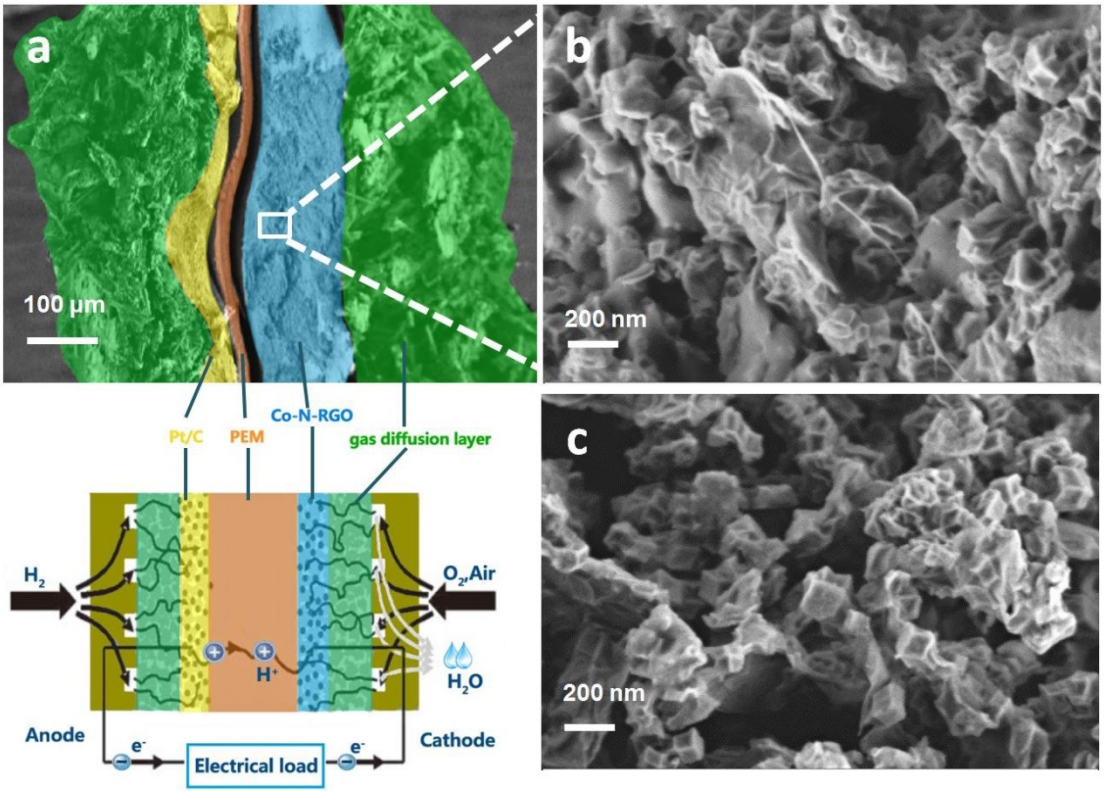

Fig. S10 SEM images of Co-N-RGO-1.5, (a) MEA and schematic diagram, (b) after MEA test, (c) before MEA test