Supporting Information

Bridging Energy Conversion and Storage: Precursor-Engineered Co@CoO-Y_2O_3 Heterostructures for Oxygen Reduction Reaction and Battery-Type Supercapacitor Applications

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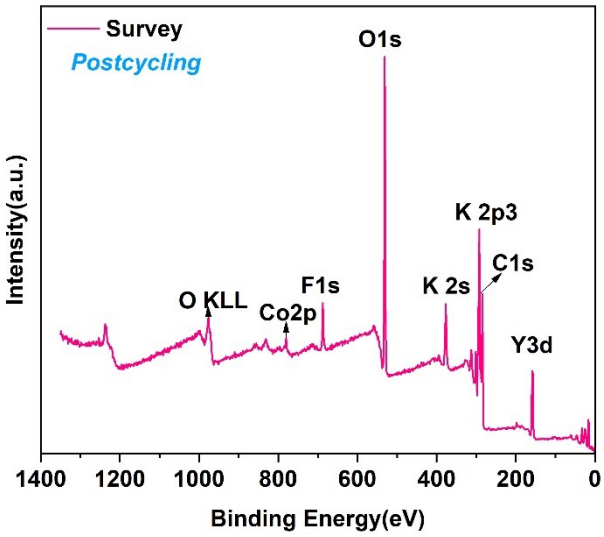

Fig. S1. The post cycling XPS survey analysis of the sample, the new peaks for K (appeared from KOH), F (from PVDF).

The *SCHERRER* formula:

The average crystallite size was calculated using the Scherrer equation:

$$\text{Crystallite size (D)} = K \times \lambda / (\beta_{size} \times \cos\theta)$$

where D is the average crystallite size, K is the shape factor (typically taken as 0.9), λ is the X-ray wavelength, θ is the Bragg diffraction angle, and β_{size} is the peak broadening related to crystallite size.

The mean lattice strain (lattice distortion) was determined using the tangent formula:

$$\text{Lattice strain } (\varepsilon) = \beta_{strain} / (4 \times \tan\theta)$$

where ε represents the lattice strain, and β_{strain} corresponds to the strain-induced peak broadening.

The structural broadening (β) was obtained by correcting the observed peak broadening for instrumental effects using a standard reference sample. The size-related and strain-related broadening were calculated using the following relations:

$$\beta_{size} = \beta_{obs} - \beta_{std}$$

$$\beta_{strain} = \text{square root of } (\beta_{obs}^2 - \beta_{std}^2)$$

where β_{obs} is the integral breadth of the diffraction peak of the sample and β_{std} is the instrumental broadening obtained from the standard material.[S1]

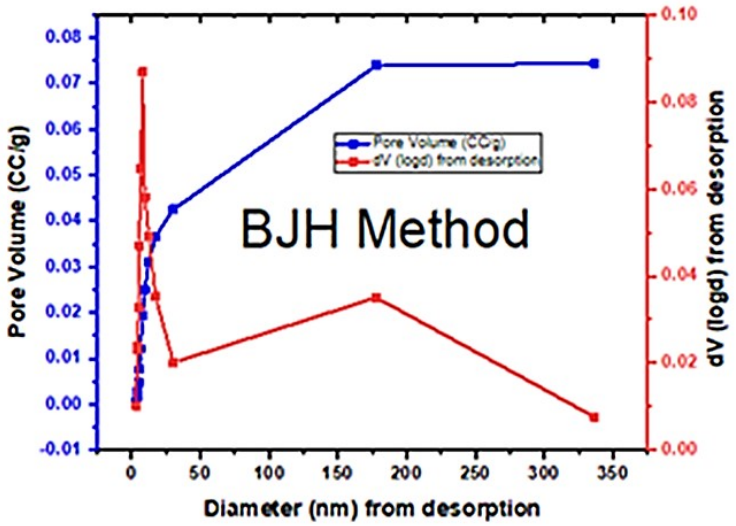

Fig. S2. Diameter vs pore volume curve

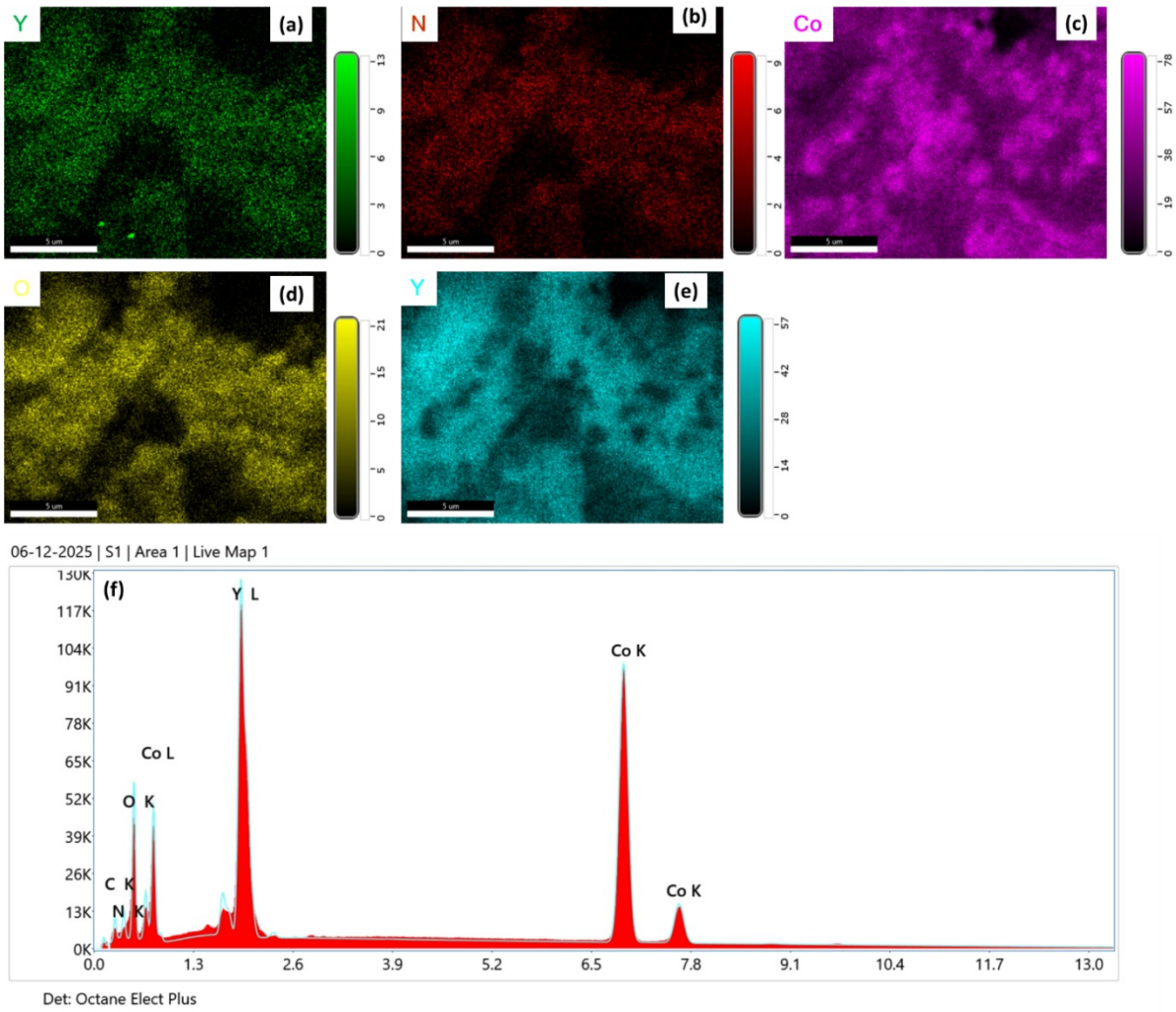

Fig.S3. (a-e) EDX elemental mapping of elements present in catalyst sample, (f) EDX spectrum as obtained from analysis.

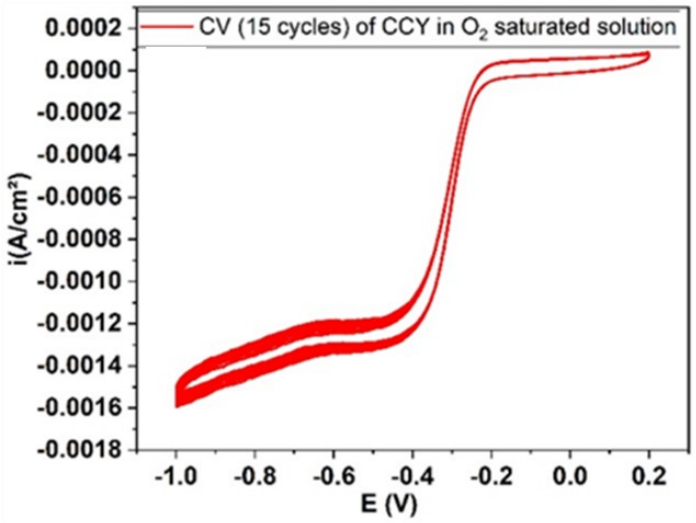

Fig. S4. CV of CCY at O_2-saturated electrolyte

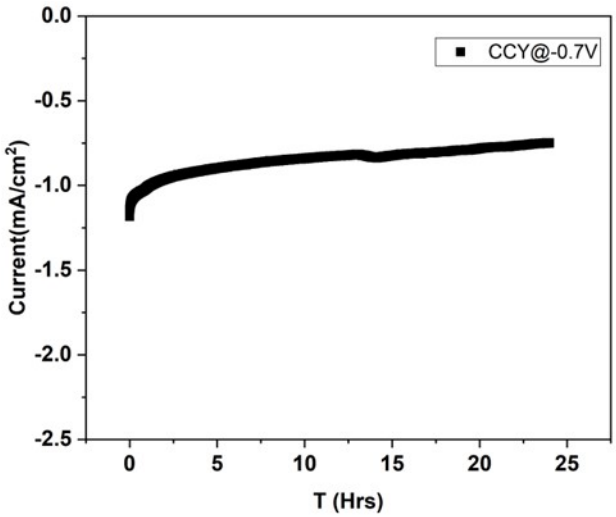

Fig. S5: Stability test (Time vs Current plot) of CCY sample.

Table S1. Different Cobalt oxide-based ORR catalysts

Catalyst	Onset Potential (V)	Half-wave Potential (V)	Electrolyte	Reference
Co@CoO/Y_2O_3 (This work)	**0.602**	**0.728**	1 M KOH	This work
Co–CoO@NC/NC	0.961	0.868	0.1 M KOH	S2
Co/Co_3O_4@N-doped carbon	0.94	0.85	0.1 M KOH	S3
CoO/$CoFe_2O_4$ /N-doped porous carbon	0.934	0.865	0.1 M KOH	S4
Co@C NPs-2h	0.99	0.76	0.1 M KOH	S5

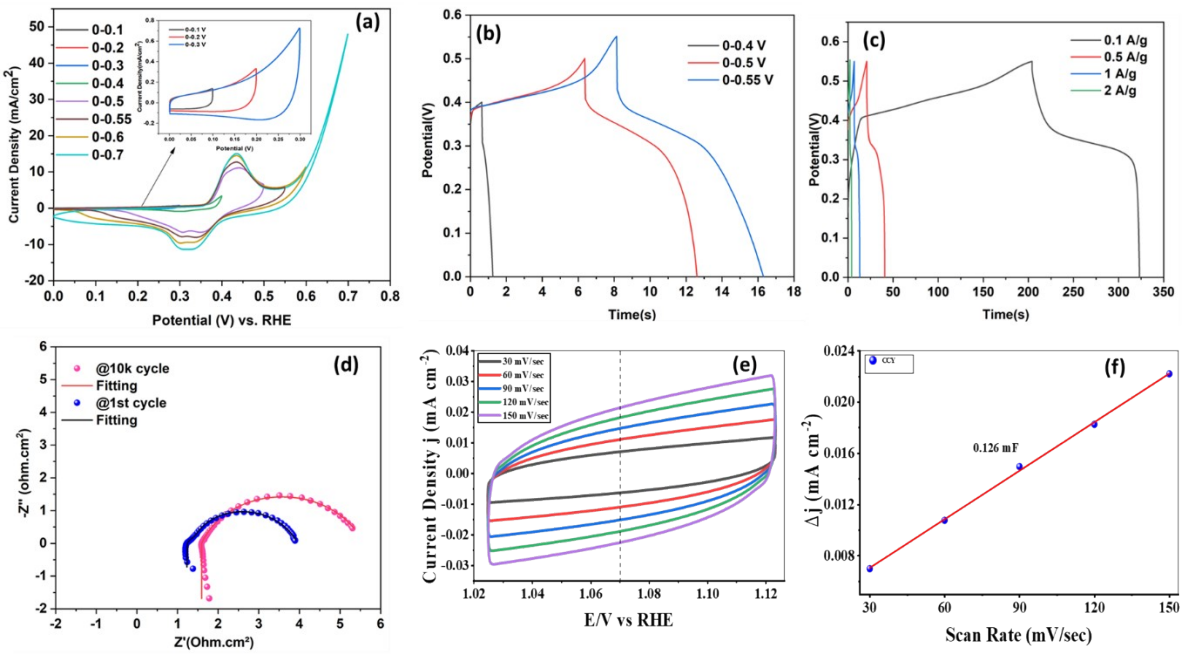

Fig. S6. For the selection of potential window from 0-0.55V and the current response is not linear above the 0-0.55 V (a-b), (c) The GCD response of CCY in KOH at different constant current, (d) The Fitted EIS plot for 1st GCD cycle and after 10000 GCD cycles, (e) ECSA calculation the non-faradic zone, (f) the C_{dl} calculation and linear fit of the current change with scan rate.

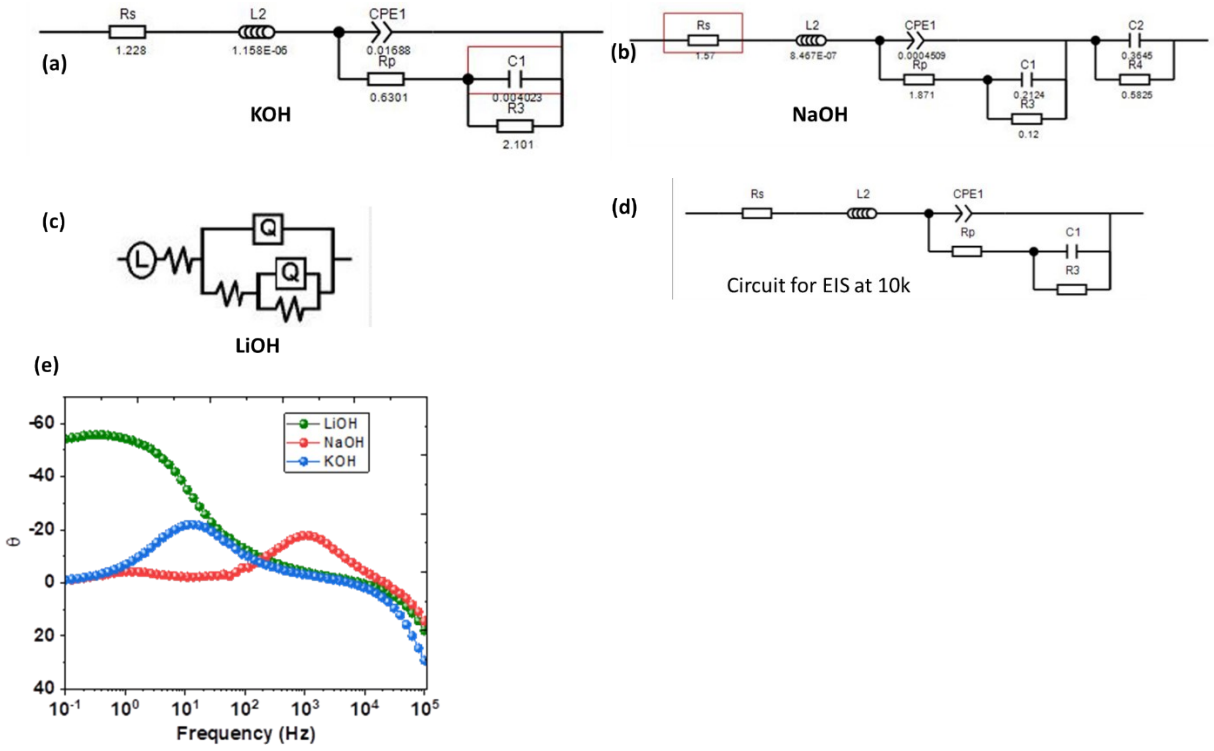

Fig. S7. (a-d) The various circuit diagram used to fit the EIS spectra, (d) Comparison of bode plot as investigated in different electrolytes.

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