Supporting Information

Application of Non-precious Bifunctional Catalysts for Metal-Air Batteries

Steffen Haller, Vladislav Gridin, Kathrin Hofmann, Robert W. Stark, Barbara Albert, Ulrike I. Kramm

Calculation of the H2O2 yield and the electron transfer number *n*app was conducted based on the measured disc current *j*disc and ring current *j*ring using the following formula:[1]

|  |  |  |
| --- | --- | --- |
|  |  | (S1) |

and

|  |  |  |
| --- | --- | --- |
|  |  | (S2) |

with the collection efficiency of the ring *N*ring = 0.38.

From the obtained slopes *m* in the KL plots, *n*KL was calculated by the following formula:[2]

|  |  |  |
| --- | --- | --- |
|  |  | (S3) |

with *F* = 96485 C mol–1, *D*0 = 1.9∙10–5 cm2 s–1, *ν* = 0.01 cm2 s–1 and *c*O0 = 1.2∙10–6 mol cm–3.

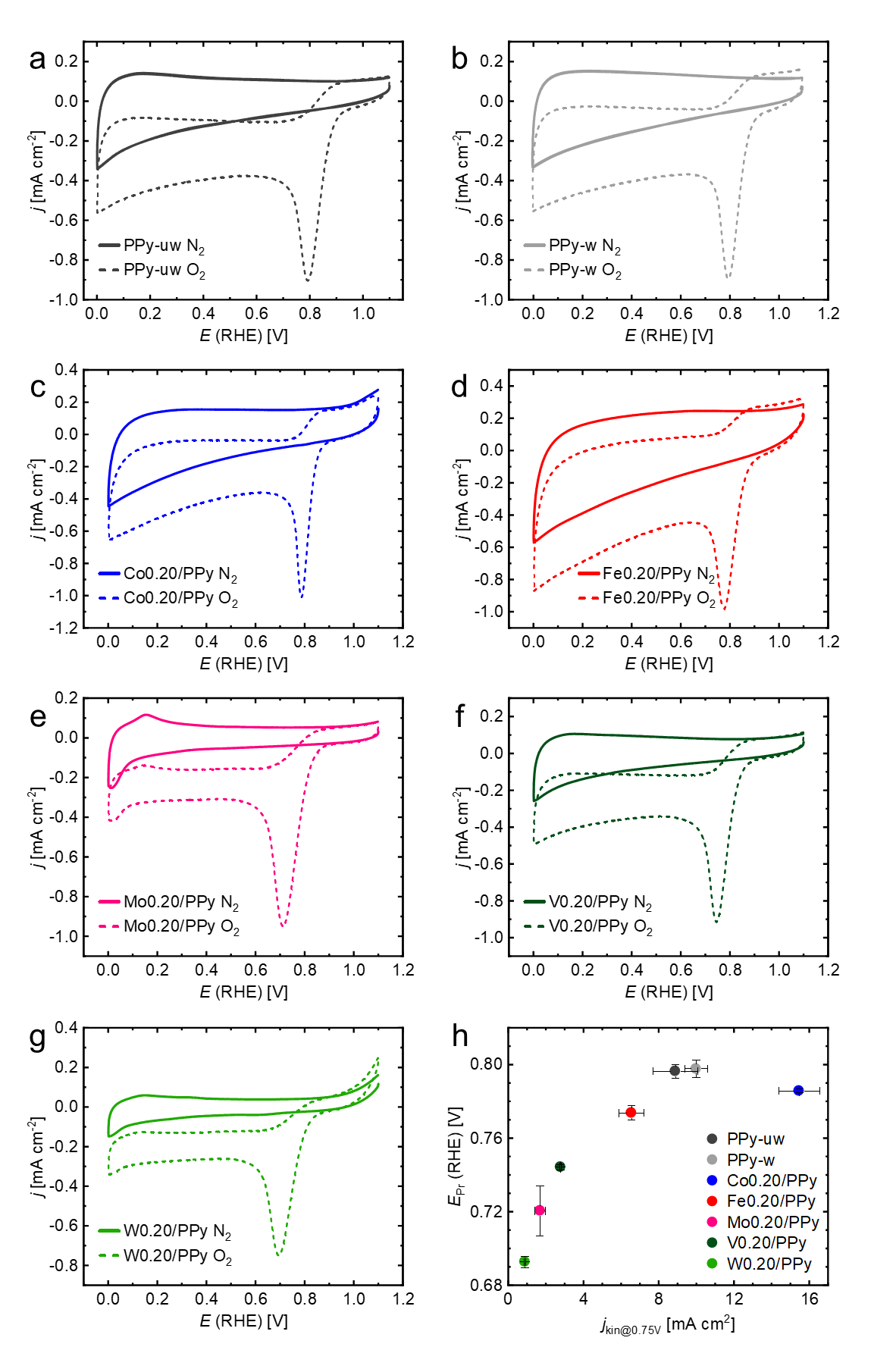


Figure S1: Cyclic voltammograms in N2- and O2-saturated electrolyte, recorded at scan rates of 10 mV s–1: (a) PPy-uw, (b) PPy-w, (c) Co0.20/PPy, (d) Fe0.20/PPy, (e) Mo0.20/PPy, (f) V0.20/PPy, (g) W0.20/PPy, (h) peak reduction potentials EPr plotted against kinetic current densities at 0.75 V.

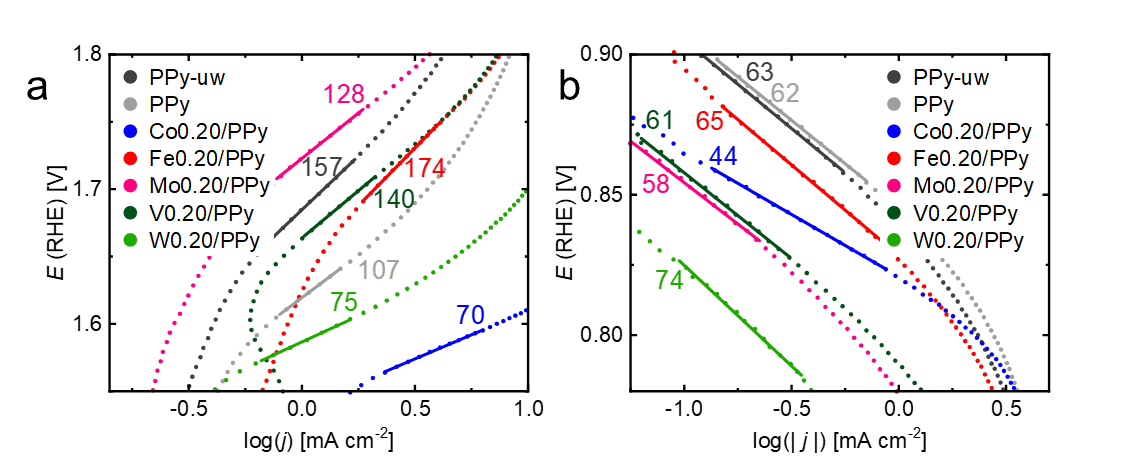


Figure S2: Transition metal variation series: (a) OER Tafel plots, (b) ORR Tafel plots, with Tafel slopes in mV dec–1.

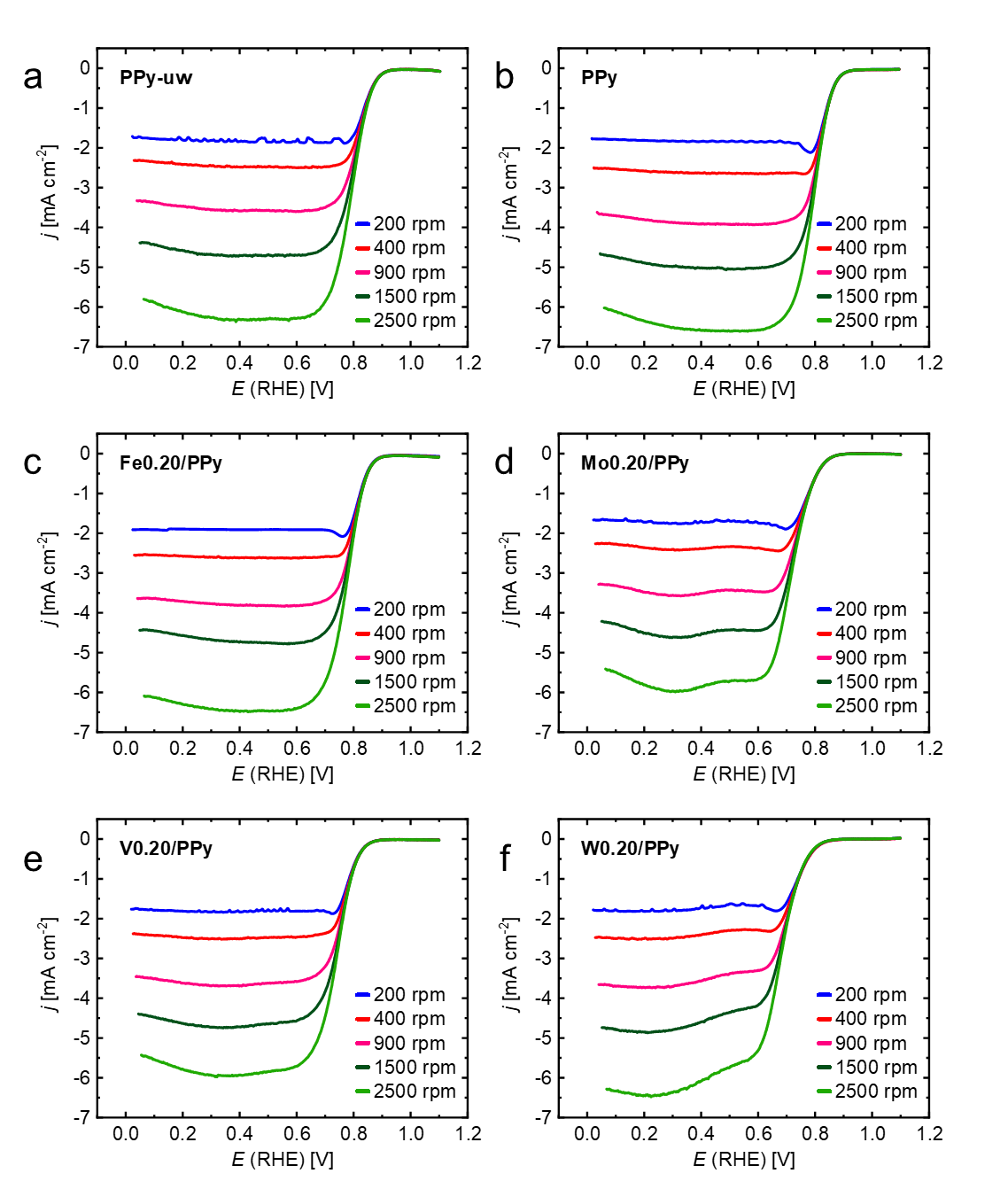


Figure S3: ORR curves recorded at 200, 400, 900, 1500 and 2500 rpm for (a) PPy-uw, (b) PPy, (c) Fe0.20/PPy, (d) Mo0.20/PPy, (e) V0.20/PPy, (f) W0.20/PPy.

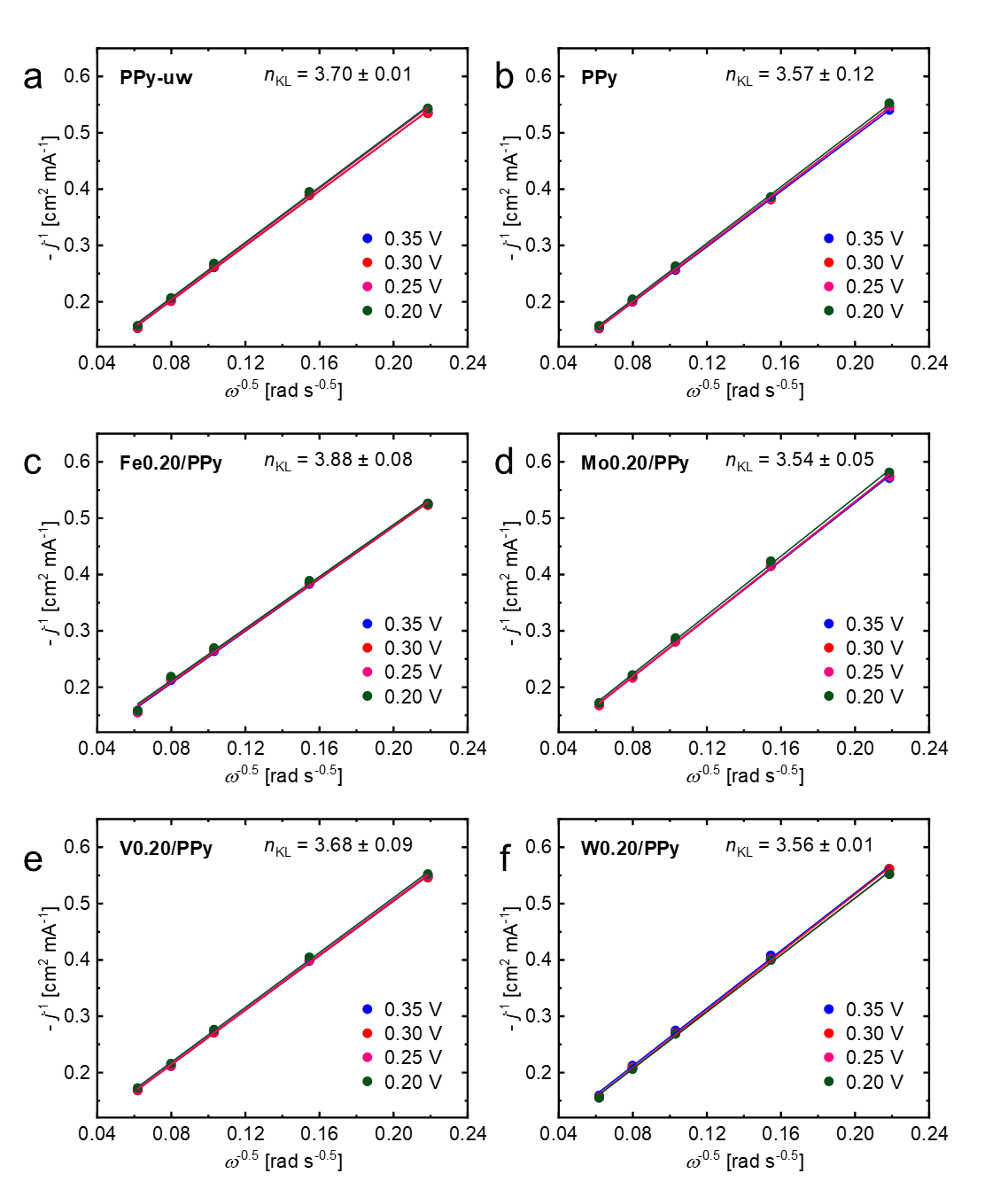


Figure S4: Koutecký-Levich plots of (a) PPy-uw, (b) PPy, (c) Fe0.20/PPy, (d) Mo0.20/PPy, (e) V0.20/PPy, (f) W0.20/PPy.

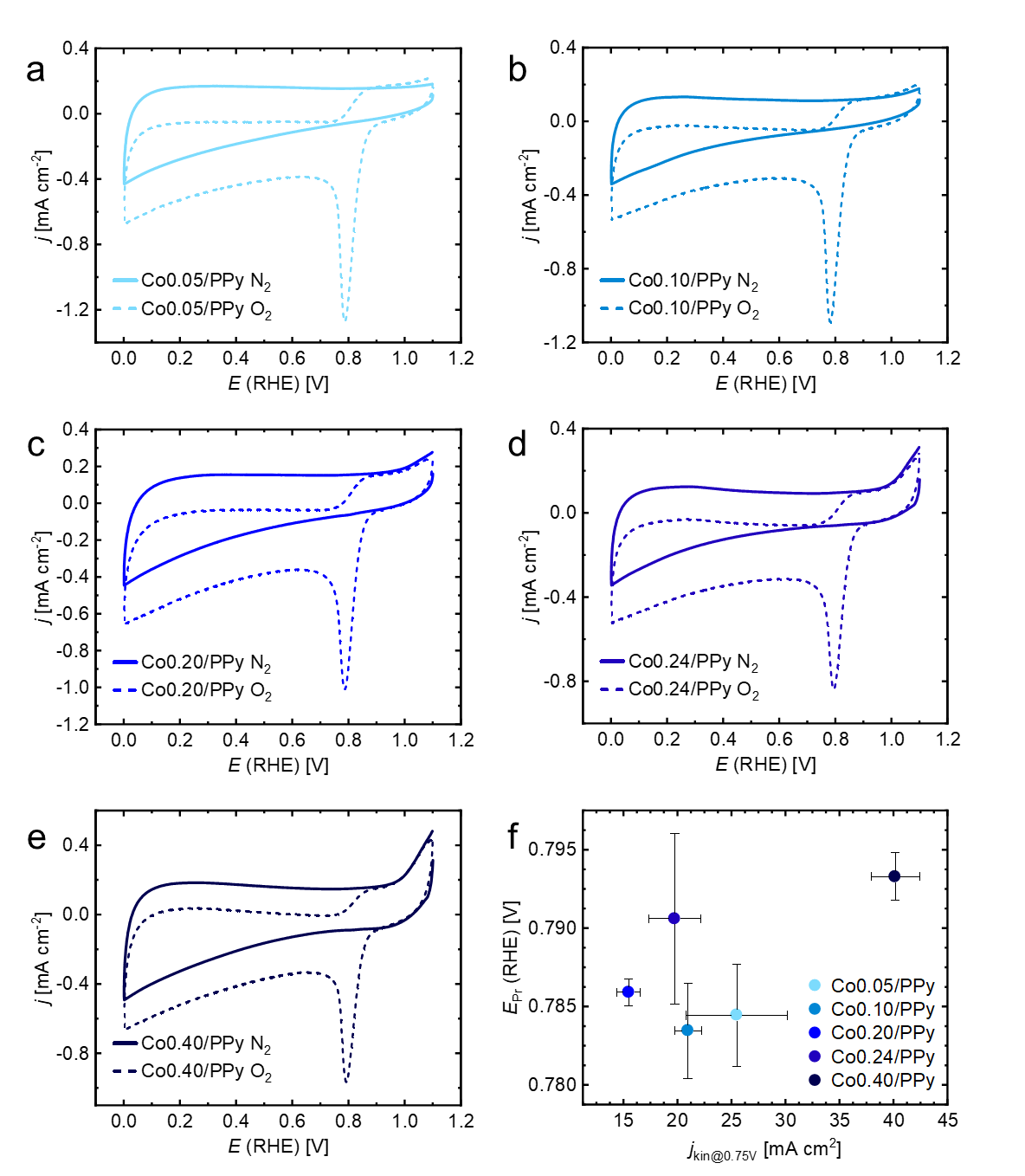


Figure S5: Cyclic voltammograms in N2- and O2-saturated electrolyte, recorded at scan rates of 10 mV s–1: (a) Co0.05/PPy, (b) Co0.10/PPy, (c) Co0.20/PPy, (d) Co0.24/PPy, (e) Co0.40/PPy, (f) peak reduction potentials EPr plotted against kinetic current densities at 0.75 V.

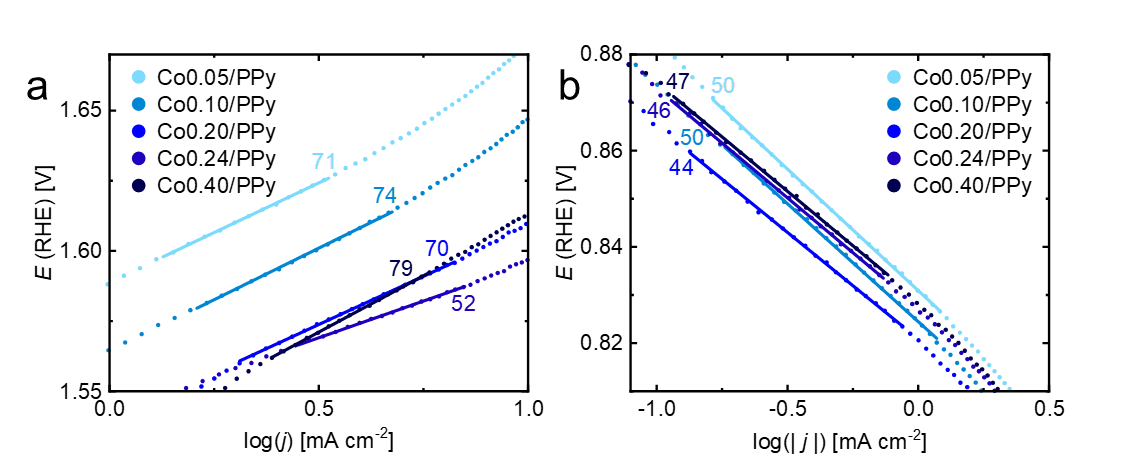


Figure S6: Cobalt loading variation series: (a) OER Tafel plots, (b) ORR Tafel plots, with Tafel slopes in mV dec–1.

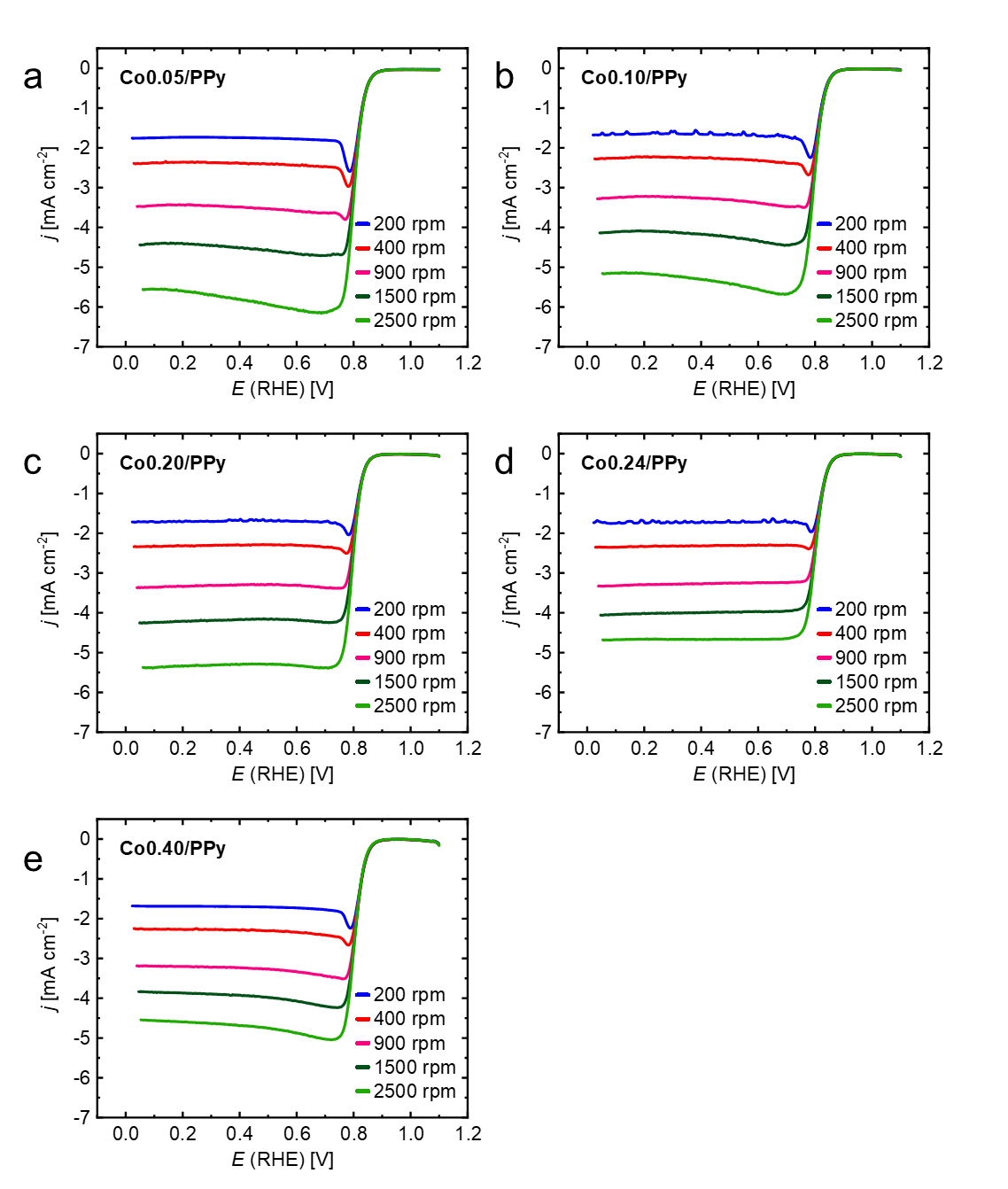


Figure S7: ORR curves recorded at 200, 400, 900, 1500 and 2500 rpm for (a) Co0.05/PPy, (b) Co0.10/PPy, (c) Co0.20/PPy, (d) Co0.24/PPy y, (e) Co0.40/PPy.

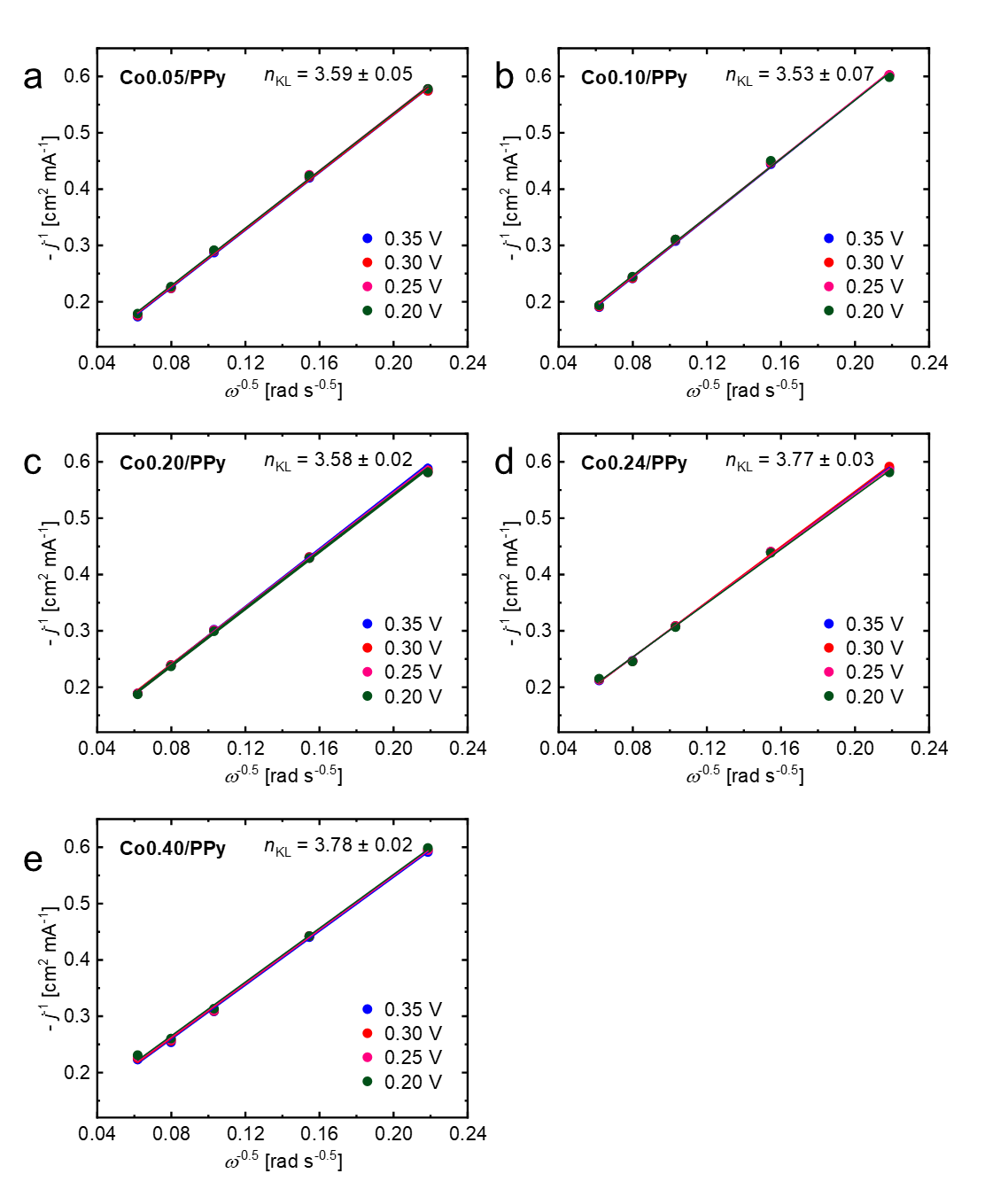


Figure S8: Koutecký-Levich plots for (a) Co0.05/PPy, (b) Co0.10/PPy, (c) Co0.20/PPy, (d) Co0.24/PPy y, (e) Co0.40/PPy.

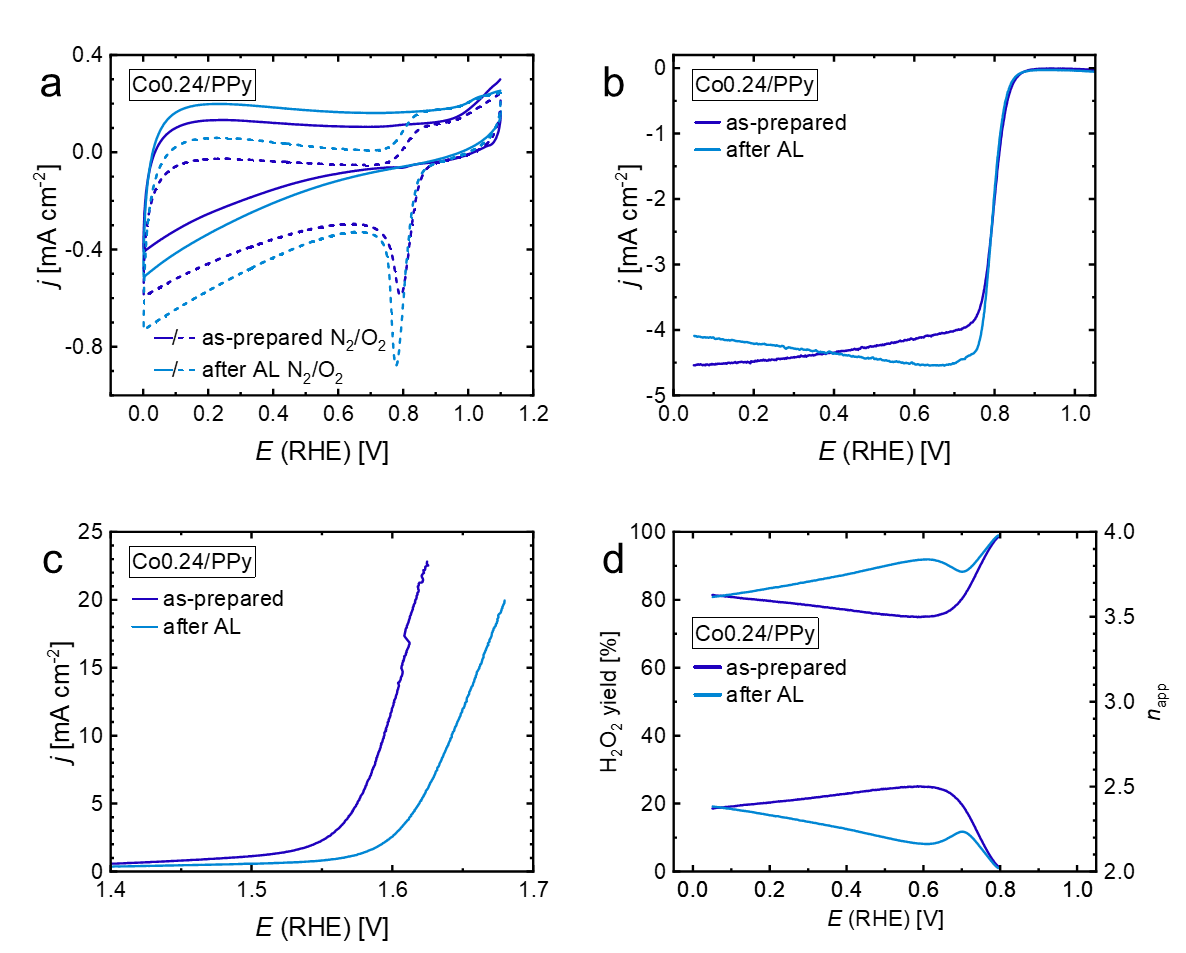


Figure S9: Acid-leaching (AL) of Co0.24/PPy: (a) CVs recorded in N2- and O2-saturated electrolyte (0 rpm, 10 mV s-1), (b) ORR curves recorded in O2-saturated electrolyte (1500 rpm, 10 mV s-1), (c) OER curves recorded in N2-saturated electrolyte (1500 rpm, 5 mV s-1), (d) peroxide yield and apparent electron transfer number. Please note that the catalyst displayed here was prepared from a different polypyrrole batch as well as a larger microwave pyrolysis batch.

[1] Z. Jia, G. Yin, J. Zhang, *Rotating Ring-Disc Electrode Method*, in: *Rotating electrode methods and oxygen reduction electrocatalysts* (Eds: W. Xing, G. Yin, J. Zhang), Elsevier **2014**, 199 – 229.

[2] C. Dua, Q. Tana, Yina. G, J. Jiujun Zhangb, *Rotating Disk Electrode Method*, in: *Rotating electrode methods and oxygen reduction electrocatalysts* (Eds: W. Xing, G. Yin, J. Zhang), Elsevier **2014**, 171 – 198.