Supporting Information

Improved electrical power production of thermally regenerative batteries using a poly(phenylene oxide) based anion exchange membrane

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Equations describing chemical consumption of copper in the cathode with ammonia:

$$NH_4^+ = NH_3 + H^+ \quad , \quad pK_a=9.25 \qquad (S1)$$

$$Cu^{2+} + NH_3 = [Cu(NH_3)]^{2+} \quad , \quad pK_1=-4.25 \qquad (S2)$$

$$[Cu(NH_3)]^{2+} + NH_3 = [Cu(NH_3)_2]^{2+} \quad , \quad pK_2=-3.61 \qquad (S3)$$

$$[Cu(NH_3)_2]^{2+} + NH_3 = [Cu(NH_3)_3]^{2+} \quad , \quad pK_3=-2.98 \qquad (S4)$$

$$[Cu(NH_3)_3]^{2+} + NH_3 = [Cu(NH_3)_4]^{2+} \quad , \quad pK_4=-2.24 \qquad (S5)$$

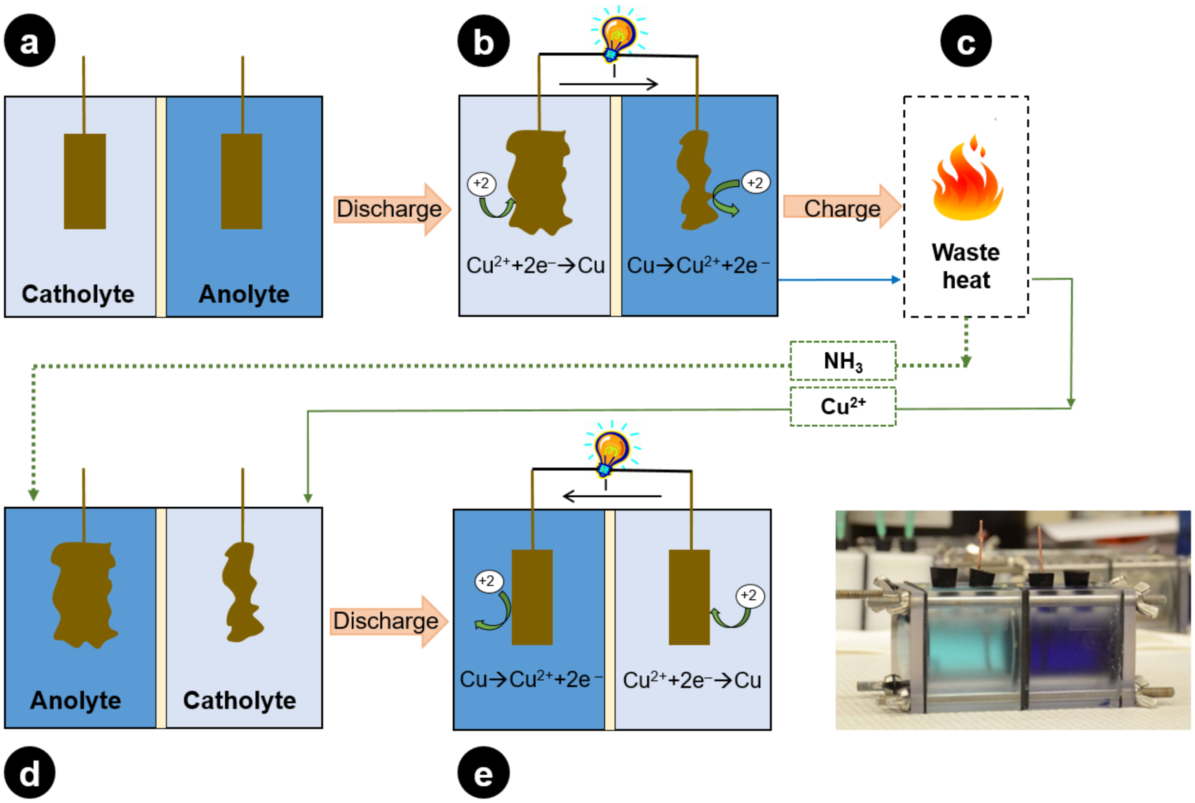

Figure S1. Schematic of the TRAB used to convert waste heat to electricity: (a) A potential difference is generated between the cathode and anode chamber containing a copper nitrate salt by addition of ammonia to the anolyte (dark blue); (b) Cell discharge resulting in corrosion of the anode, and copper deposition on the cathode; (c) Ammonia removal from the anolyte using a distillation column operated with low grade waste heat as the energy source; (d) Switching the chambers by adding ammonia to the other chamber, so that the former anolyte electrode now becomes the catholyte chamber; (e) Discharge of the TRAB, which ideally will fully regenerate the electrodes through removal of the additional copper from the anolyte electrode and deposition onto the catholyte electrode.

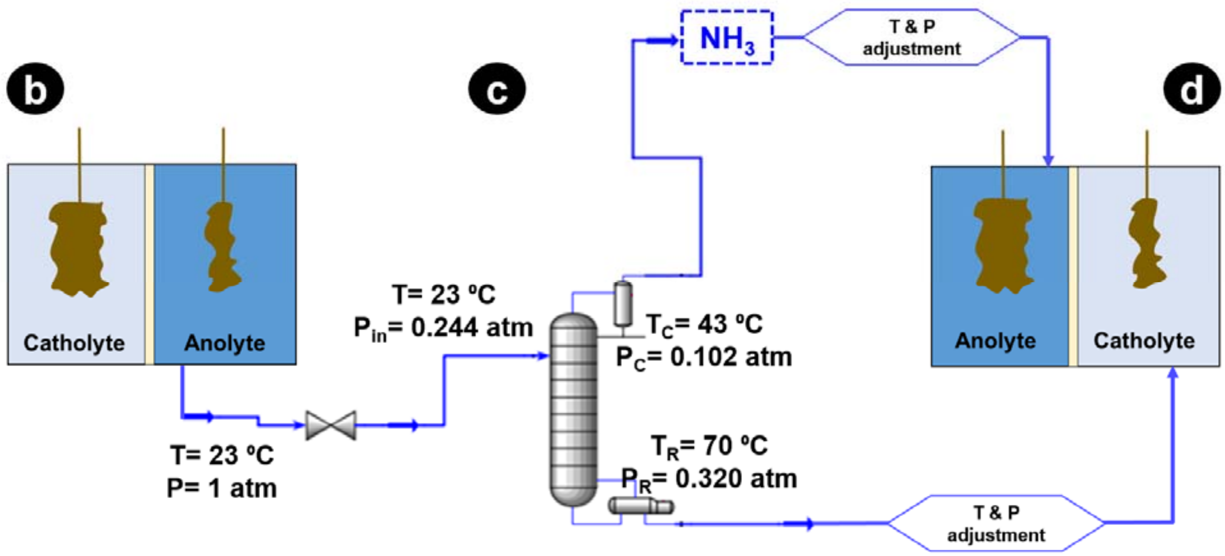

Figure S2. Schematic of the separation unit (battery charge) based on a distillation column with a reboiler temperature of 70.4 ºC, and a condenser temperature of 43.3 ºC. The input concentration of ammonia is 2 M, and 97% of this component is separated off from the top stream. The separation is modeled in a column with 6 trays with the non-random two-liquid (NTRL) thermodynamics model using Aspen HYSYS software. The letters "b", "c", and "d" refer to the same unit described in Fig. S1.

Figure S3. Synthetic route of poly(2,6-dimethyl phenylene oxide) with benzyltrimethyl ammonium cation AEMs (Bx; x=25, or 40).

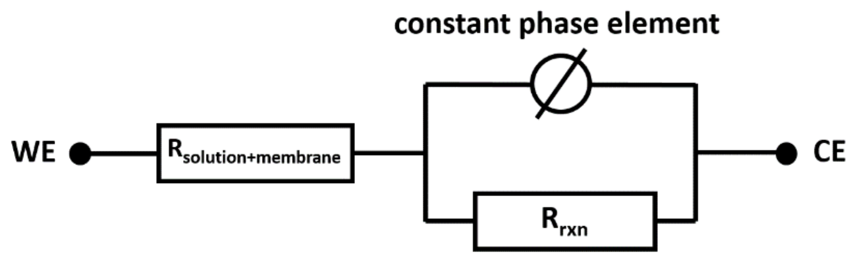

Figure S4. Equivalent circuit for the cell impedance analysis to measure the membrane resistance.

Solution resistance can be calculated using solution conductivities as:

$$R_{\text{solution}} = \frac{l}{A}\left(\frac{1}{\sigma_{\text{an}}} + \frac{1}{\sigma_{\text{cat}}}\right) \tag{S6}$$

where l is the distance between electrode and membrane (1.14×10^{-2} m), A is the internal area of the reactor (7×10^{-4} m^2), and σ_{an} and σ_{cat} are solution conductivities of anolyte and catholyte, respectively. Membrane resistance was calculated by subtracting solution resistance from the solution/membrane resistance measured by the EIS:

$$R_{\text{membrane}} = R_{\text{solution/membrane}} - R_{\text{solution}} \tag{S7}$$

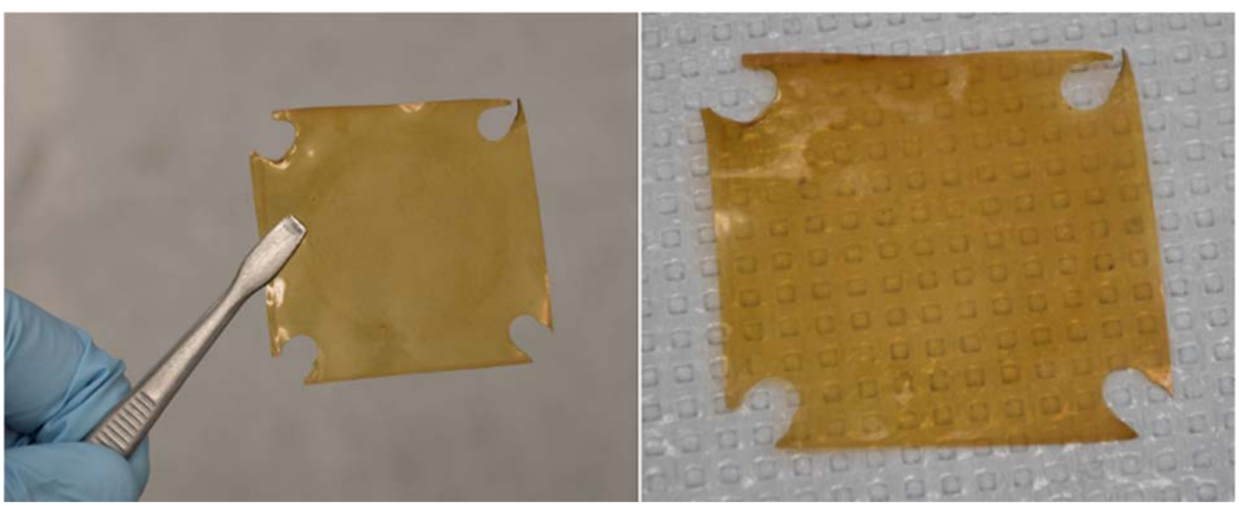

Figure S5. Image of B40-50 fabricated AEM after a period of one year.