Electronic Supplementary Material (ESI) for Energy & Environmental Science.

- Supporting Information -

A thermally regenerative ammonia-based battery for efficient harvesting of low-grade thermal energy as electrical power

Fang Zhang, Jia Liu, Wulin Yang and Bruce E. Logan*

Department of Civil and Environmental Engineering, Penn State University,

212 Sackett Building, University Park, PA 16802, USA

* Corresponding Author, blogan@psu.edu;

+1-814-863-7908 (phone), +1-814-863-7304 (Fax)

Nernst equations for calculating electrode potentials:

Anode: $$E = E^0 - \frac{RT}{2F} ln \frac{[a(NH3)]^4}{a(Cu(NH3)42+)}$$ ---- (S1)

Cathode: $$E = E^0 - \frac{RT}{2F} ln \frac{1}{a(Cu^{2+})}$$ ---- (S2)

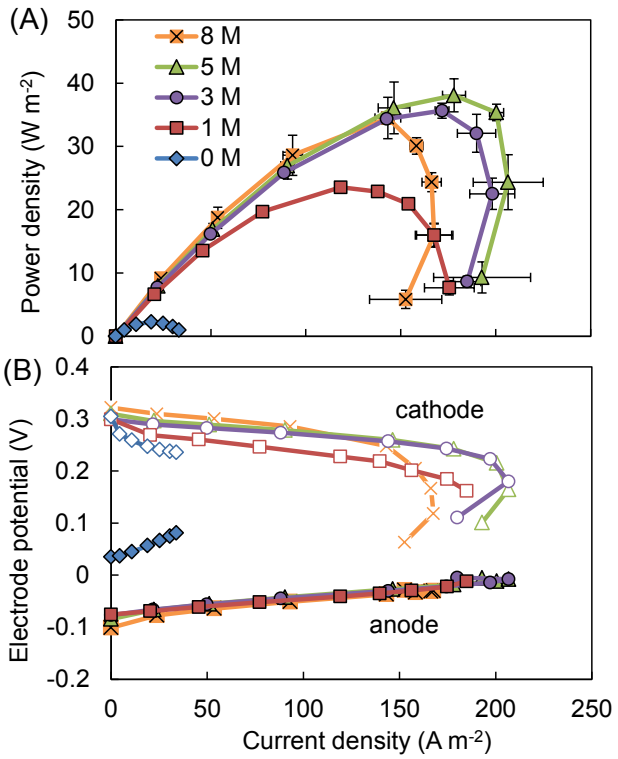

Figure S1. (A) Power production and (B) electrode potentials using 0 – 8 M NH_4NO_3 as the supporting electrolyte, with 0.1 M Cu(II) in both electrolyte and 1 M ammonia in the anolyte. Both catholyte and anolyte were in static conditions. Error bars represent standard deviations based on measurements with duplicate reactors. Cathode concentration polarization occurred at high current density range with 3 – 8 M NH_4NO_3, resulting in power overshoot with these conditions.

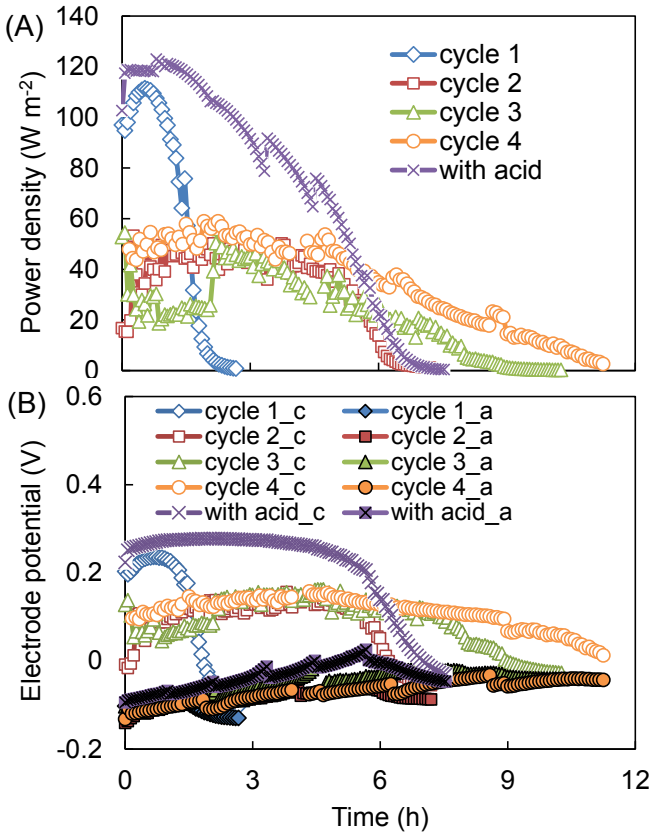

Figure S2. Whole batch cycle performance (A) power density (B) electrode potentials of four successive cycles. The initial electrolyte contained 0.1 M Cu(II), 5 M NH_4NO_3 and additional 2 M NH_3 in the anolyte. The electrolyte was then thermally regenerated and operated for 3 successive cycles. "With acid" stands for the condition where acid was added to dissolve the $Cu(OH)_2$ precipitates during the catholyte regeneration.

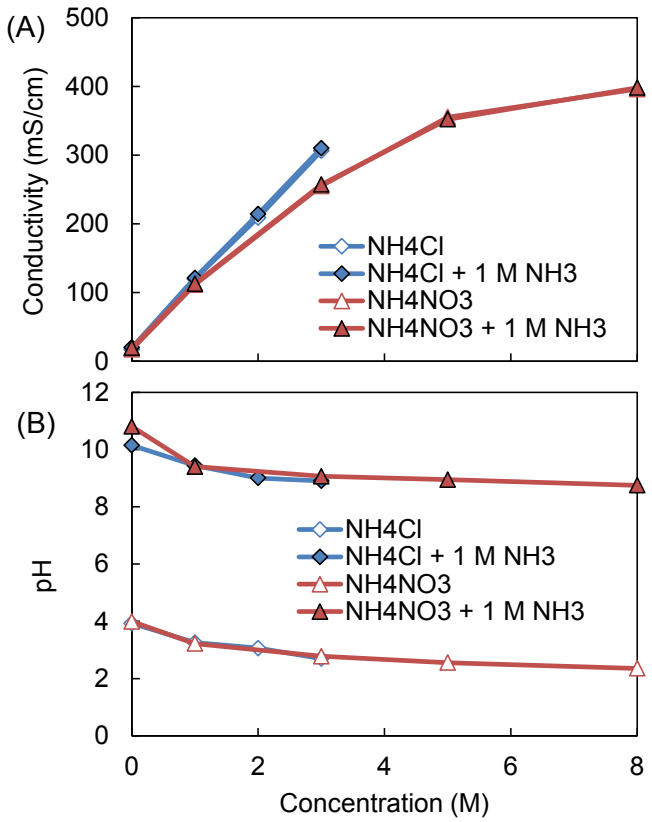

Figure S3. (A) Conductivity and (B) pH of 0.1 M $Cu(NO_3)_2$ solutions with various concentrations of ammonium salts, with or without addition of 1 M ammonia in the solutions. Given the same molar concentration of salt, although NH_4Cl had a higher conductivity than NH_4NO_3, the formation of $CuCl_4^-$ complex ions prevented the use of NH_4Cl as the supporting electrolyte.

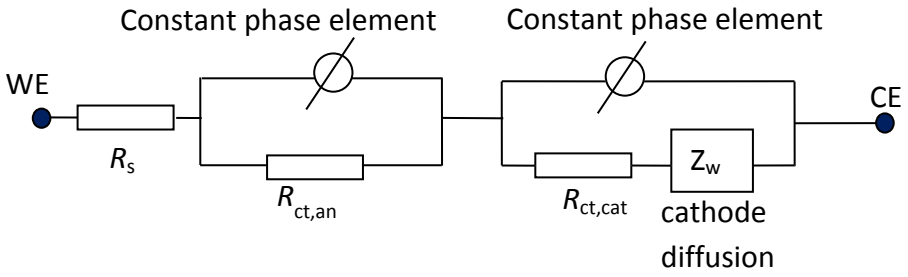

Figure S4. Equivalent circuit for whole cell impedance analysis. The reaction resistance was the sum of anode charge transfer resistance ($R_{ct,an}$), cathode charge transfer resistance ($R_{ct,cat}$), and diffusion resistance ($R_{d,cat}$).