Dissecting the quinone bromide flow battery

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Dissecting the Quinone Bromide Flow Battery

Qing Chen, Michael R. Gerhardt, Louise
Eisenach, Michael P Marshak,
Roy G Gordon, Michael J Aziz.

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Quinone-bromide flow battery

References:

- Huskinson, Brian, et al. *Nature* 505.7482 (2014): 195-198.
- Huskinson, Brian, et al. *ECS Transactions* 61.37 (2014): 27-30.

QBFB reaches 1.0 W/cm²

Black: base case

Red: high power build

Electrode	Membrane	Flow rate	Temperature	Posolyte
Baked SGL 10AA	Pretreated 212	200 mL/min	20 °C	3 M HBr, 0.5 M Br ₂
SGL 10AA	212	100 mL/min	30 °C	3.5 M HBr, 0.5 M Br ₂
Etched Toray 060	115	50 mL/min	40 °C	2.5 M HBr, 0.5 M Br ₂
•	•	•	•	•
•	•	•	•	•
Baked SGL 10AA	Pretreated 212	400 mL/min	45 °C	3 M HBr, 2 M Br ₂

When kinetics and mass transport limits are insignificant, polarization curves are linear

Ohmic resistors in the cell

We may use linearized Butler-Volmer

Separating voltage losses

Membrane ionic + electronic (+ & -)
104 mΩ cm²

Membrane ionic: 60 mΩ cm²
Electronic: 22 mΩ cm² (each)

Separating voltage losses

Electrolyte ionic (+) + Faradaic (+)

94 mΩ cm²

Electrolyte ionic (-) + Faradaic (-)

127 mΩ cm²

< 10 mΩ cm²

Membrane ionic + Electronic (+ & -)

104 mΩ cm²

Two phase conducting and Current distribution

Current distribution curves at a fixed i_{tot}

1D homogeneous porous electrode model neglecting mass transport

$$i_{\text{tot}} = i_s + i_l$$

$$i_s = \nabla \phi_s / \rho_s \quad i_l = \nabla \phi_l / \rho_l$$

$$i_f \propto \nabla \cdot i_s = f[\phi_s - \phi_l]$$

$$\text{Overvoltage } \eta_{\text{nego}} = \phi_1 - \phi_2 \approx \int_0^L i_l(x) \rho_l dx$$

$$\text{Resistance } r_{\text{nego}} = \frac{\eta_{\text{nego}}}{i_{\text{tot}}} = \rho_l \int_0^L \frac{i_l(x)}{i_{\text{tot}}} dx$$

Reference

Newman, John and Thomas-Alyea, Karen.
Electrochemical Systems, 3rd edition, Wiley

Potential probes for current distribution

$$i_s = V_{1, 2 \text{ or } 3} / r_{1, 2 \text{ or } 3}$$
 Measured by EIS

All i_s/i_{tot} appear independent of i_{tot}

Overvoltage from the negative side

$$r_{nego} = \frac{\eta_{nego}}{i_{tot}} = \rho_l \int_0^L \frac{i_l(x)}{i_{tot}} dx$$

Neg. $\rho_l \sim 2.2 \Omega \text{ cm}$
($\sim 5.4 \Omega \text{ cm}$ after Bruggeman
correction using 55% porosity)

Line & scatters: experimental values
Dashed lines: 1D porous electrode model

161 mΩ cm²
Electronic + Electrolyte Ionic + Faradaic

All i_s/i_{tot} appear independent of i_{tot}

Conclusions

- Highest QBFB peak power density to date: 1.0 W/cm²
- Linear polarization for QBFB
- Contributions to overvoltage have been quantified
- Negative Faradaic reaction occurs primarily in the first 300 μm of the electrode
- Enables future engineering improvements

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Fig. 5. The potential profile and current distribution for symmetric electrodes geometry under secondary current distribution (Wa (anode) = 0.1, Wa (cathode) = 100).

i_app(25)=50000 Surface: Velocity field, x component (m/s)