Project Outcomes

Membraneless flow battery technology may reduce the cost of flow batteries, which are promising candidates for grid-scale energy storage, but are still too expensive to reach wide use. Using similar technology, membraneless fuel cells had achieved high power densities, but, before this project, the extensive cycling required for battery operation had not yet been demonstrated in a membraneless flow cell. The goals of this project were to design, build and test a second-generation hydrogen-bromine membraneless flow battery for high power density, cyclability, and scalability, to test this battery in cycling experiments, noting failure modes, and to develop a computational model of flow and species distribution in a microfluidic fuel cell with a flow-through porous electrode.

The battery prototype was designed to meet the project goals using a heterogeneous porous architecture. The power density of the hydrogen-bromine cell, already high due to fast kinetics, was further improved by reducing hardware resistance. The use of a flow-through porous cathode enhanced power and scalability, preventing the growth of depletion boundary layers along the cell. The heterogeneous porous architecture also included a small-pore layer separating the cathode from the electrolyte channel in order to reduce crossover and improve cyclability.

Simulation runs were used to examine the characteristics of the flow and mass transfer within the micro-channel by analyzing the effects of the Reynolds number, height of the main channel, and the inlet velocity of the secondary channel. Based on volume-averaging method the steady state model governing the equations for momentum and concentration within the porous cathode was used for parametric studies.

Simulation runs shows that increasing Reynolds number results in high flow recirculation and higher mass transfer rates. The concentration of species along the exit of the secondary channel decreases with an increase in the Reynolds number. Furthermore as the channel height decreases, the mass boundary layer thickness decreases along the walls of the secondary channel and consequently increases mass transfer rates. The simulation agrees with the experimental results that the channel height play an important role in the performance of the microfuel cell and it is preferred to operate the microfuel cell at higher Reynolds number for better performance.

A primary outcome of this study was the experimental demonstration of a power density of 925 mW/cm^2 and up to 33 cycles with the prototype battery. Further work will focus on improving sealing to reach a higher number of cycles and redesigning the battery for higher efficiency.