

STEM

Flow Analysis in a Direct Borohydride-Hydrogen Peroxide Fuel-Cell Stack

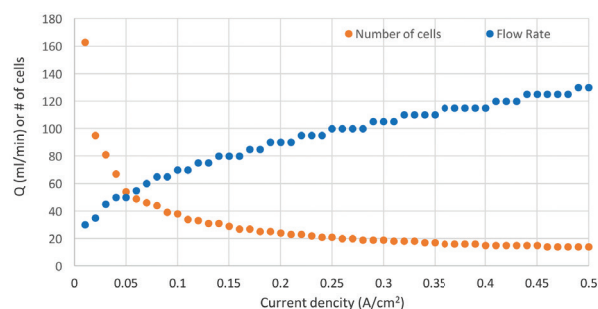
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Fuel cells are energy storage devices analogous to batteries in which electrochemical energy is directly converted into electrical energy. The main difference between a fuel cell and a battery is that a fuel cell is an open system that allows chemicals to flow through, while a battery is a closed system. As a consequence, a fuel cell can be turned off by simply stopping the flow. Fuel cells are also very energy dense, due to the fact that it is possible to store the chemicals that flow through them in separate tanks. Additionally, fuel cells do not pollute and, in theory, have a high current efficiency, making them an ideal long-lasting, flexible power source.

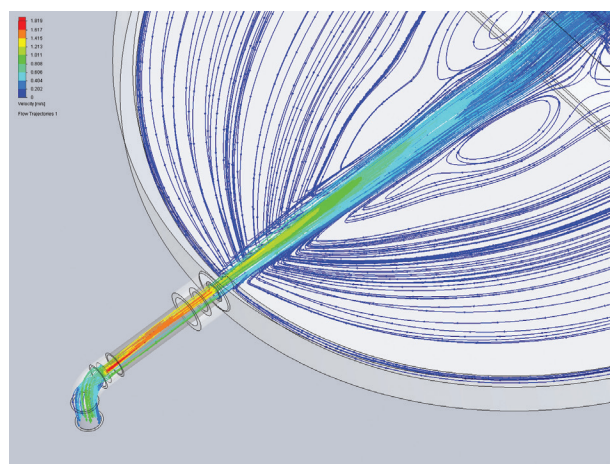
Early research in direct borohydride–hydrogen peroxide fuel cells has been promising, although most of the work to date has been done on a single cell that has low power output. In order to increase the power output, multiple cells need to be stacked together. The design and assembly of a low-cost, effective fuel-cell stack is a topic for further investigation.

The focus of this project was the development of a computational fluid dynamics model, using SolidWorks Flow Simulation, for the flow in a fuel cell with ionic potassium borohydride as the fuel and hydrogen peroxide as the oxidizer. Once the flow model was developed and verified, it was used in conjunction with a system chemistry model to determine the maximum number of cells that can be stacked and the corresponding flow rate necessary for every cell to produce power without running out of reactant. Design requirements limited the pressure drop across the stack to 10 psi, and the solution was dependent on the current density of test cells. Results from this study show that a test cell producing 0.4 A/cm² can be scaled up to a stack of 15 cells with a flow rate of 115 ml/min. Detailed analysis of the flow through a single cell was also conducted to determine possible locations for design improvement to accommodate high-power stacks (50 or more cells). The most important issue to address when redesigning the stack is the reduction of the differential pressure at the inlet and outlet of the cell by eliminating the use of narrow tubing.

Research advisors Don Mueller and John Rusek write: “Akis’s work on this project involving the development of fuel cells is what engineering is all about. He applied mathematical modeling and computer simulation to help transform a scientific concept into a useful technology. Great job!”



Relationship between the current density, the maximum number of stacked cells, and the required flow rate. The pressure drop across the stack is limited to 10 psi.



Flow trajectories through the cell showing locations of high velocity.