

Researchers are studying failures in fuel cells to learn how to improve their durability and reduce cost. Specifically, they are addressing the key challenges of chemical damage to membranes, carbon corrosion and instability in the platinum catalysts.

Fuel Cell Durability:

Research into Better Fuel Cell Materials and Designs Starts with Studying Failures

By Abby Vogel



Photo: Gary Meek

Tom Fuller's research shows that new materials, new manufacturing techniques and new designs are required to improve the durability of fuel cells.

Fuel cells can be expensive, and they typically don't last as long as their internal combustion counterparts.

Researchers in the Georgia Tech Research Institute's (GTRI) Center for Innovative Fuel Cell and Battery Technologies believe that understanding how and why fuel cells fail is the key to both reducing cost and improving durability.

Center Director Tom Fuller has been trying to solve what he deems the top three durability problems since he joined GTRI from United Technologies three years ago.

"My philosophy is if we can really understand the fundamentals of these failure mechanisms, then we can use that information to guide the development of new materials or we can develop system approaches to mitigate these failures," says Fuller, who is also a professor in Georgia Tech's School of Chemical and Biomolecular Engineering (ChBE).

The problems Fuller is addressing include chemical attack of the membrane, carbon corrosion and platinum instability. Fuller described progress toward solv-

ing these problems at the 212th Electrochemical Society Meeting in October 2007.

In a typical fuel cell, hydrogen is delivered to the anode side of the cell that contains a catalyst, such as platinum. The platinum splits the hydrogen molecules (H_2) into hydrogen ions and electrons. On the cathode side of the fuel cell, an oxidant such as a stream of oxygen or air is delivered.

With a proton exchange membrane in the middle, only hydrogen ions can travel through the membrane to the cathode. Electrons travel on a different path through the electrical circuit to the cathode, creating an electrical current. At the cathode, the hydrogen ions combine with oxygen and the electrons that took the longer path to form water, which flows out of the cell.

Fuller's research shows that the membrane, commonly made of a synthetic polymer, is prone to attack by free radicals that create holes in the barrier. The free radicals are formed by the decomposition of hydrogen peroxide (H_2O_2), a strong oxidizing chemical that can form near the membrane.

In a paper published in March 2007 in the *Journal of Power Sources*, Fuller and professor Dennis Hess, research scientist Galit Levitin and graduate student Cheng Chen, all from ChBE, used X-ray photoelectron spectroscopy (XPS) to study the membrane degradation. This work was funded by GTRI, ChBE and the Lawrence Berkeley National Laboratory.

The researchers chose XPS because it is a quantitative technique that uses X-rays to measure the presence and quantity of chemical elements and the formation and breakage of chemical bonds within a material.

"We were able to see chemical differences in the membrane with XPS when it went through the degradation process," explains Fuller. "Now we're trying to figure out what really limits or controls the rate of degradation."

Another challenge with low-temperature fuel cells is that a blockage can occur on the anode side of the fuel cell, possibly from a water drop formed in the fuel channel. The blockage causes carbon (used to support the platinum) to corrode, turn into carbon

dioxide and leave the fuel cell as a gas. Frequently starting and stopping the fuel cell also causes this mode of failure.

This can be catastrophic for the fuel cell because without carbon, the platinum catalyst layer collapses and disappears.


"Researchers know this problem exists, but we're trying to build physics-based detailed models to evaluate different fuel cell designs that will reduce the susceptibility to this type of corrosion," says Fuller, who's working on this project with Norimitsu Takeuchi from Toyota's material research department and students Kevin Gallagher and David Wong with funding from Toyota.

Another problem with fuel cells cycling on and off is that platinum has a small but finite solubility in the acidic membrane given the high electrical potential and oxidizing environment at the cathode.

"Platinum is one of the most expensive parts of the fuel cells, so researchers study how to decrease the amount necessary to run a fuel

cell," explains Fuller. "But if there is less platinum in the fuel cell to begin with, you can't afford to lose any by it dissolving."

When the platinum layer dissolves, a band of platinum typically forms inside the membrane. Fuller, GTRI senior research engineer Gary Gray and graduate student Wu Bi, developed a model to predict where the platinum band would form to help to understand why it was happening. This work was published in March 2007 in *Electrochemical and Solid-State Letters*.

"We found that the platinum can also be deposited throughout the membrane and it can move around to different places, but whenever it leaves where it's supposed to be, it's no longer effective," says Fuller. 

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- Tom Fuller, director, Center for Innovative Fuel Cell and Battery Technologies

Photo: Gary Meek

Researcher Tom Fuller examines a fuel cell membrane. His research seeks to understand failure mechanisms in the devices.

