Fuel Cells Transform Cars

Highly efficient vehicles with no polluting emissions

Quick read
Lab scientists are refining fuel cell technologies to create amazingly energy-efficient and eco-friendly vehicles.

Fuel cells were invented in 1839, powered the Gemini and Apollo space missions, and still provide power on the space shuttle. But perfecting them for use in cars still poses a challenge. Scientists at the Laboratory are developing new materials to make fuel cells cost-effective, durable, and vehicle-ready. One day soon, these highly efficient powerhouses could replace internal combustion engines, so that our cars burn less fuel, and give off nothing more than the harmless emission of ordinary water.

Decreasing Foreign Oil Dependence

The United States consumes much more oil than we produce domestically. In 2007, the U.S. produced 5.1 million barrels of oil per day, but consumed 20.7 million barrels per day according to the Energy Information Administration, which provides energy statistics from the U.S. government. The result is that the U.S. imports significant amounts of oil, and is dependent upon foreign countries for its oil supply.

Fuel cells, which utilize hydrogen instead of gasoline or diesel fuel, would greatly reduce that dependence.

Emissions of Pure Water

Fuel cells are similar to batteries; they convert chemical energy into electricity. However, unlike batteries, fuel cells use chemicals that are external to the fuel cell. The types of fuel cells LANL scientists develop convert hydrogen and oxygen (from air) into electricity and water. The system utilizes a thin membrane and catalysts – often made of platinum – to electrochemically convert the hydrogen and oxygen into electricity. “Of course, environmentally we love fuel cells because hydrogen plus oxygen makes water,” says Rod Borup, program manager for the Laboratory’s fuel cell program in MPA-11, the Sensors and Electrochemical Devices Group. Scientists at the Lab are developing better materials and technologies to improve the different components of the fuel cell. These improvements include decreasing the costs of the catalyst, improving the materials that make up the membranes, understanding what degrades the performance of fuel cells including the effects of fuel and air impurities, understanding water management inside the cell, and improving on-board vehicle hydrogen storage.

Superior Fuel Efficiency

One of the biggest advantages of fuel-cell powered vehicles is their efficiency as compared to conventional internal combustion engines. A gasoline-powered engine is about 22 percent efficient, Borup says. That means that 22 percent of the fuel you put into your car is used to power the vehicle, and the remainder is wasted as heat. A diesel-powered vehicle runs at about 27 percent efficiency, a hybrid electric vehicle, about 30-35 percent. By contrast, fuel cell vehicles can run at 55 percent efficiency. They simply burn less fuel.

Replacing an Old Standard

Besides the technical challenges the Lab is addressing, fuel cell acceptance may require a sea change in the public’s way of thinking. “Internal combustion engines are very reliable, and performance is good,” Borup says. “With fuel cells, we are trying to put something on the market that displaces existing technologies.” To begin to adjust the American mindset, the world’s major automakers are rolling out

prototypes of fuel cell cars. Prototype fuel cell forklifts, busses, and stationary building power supplies are in use around the globe. “Our part at the Lab is to make better materials for fuel cells, and to help give the automakers and others a better perspective on how to use fuel cells,” Borup says. The Department of Energy is targeting the year 2015 for a decision on the commercial viability of fuel cells, he says. Further, DOE's goals are to have on-board hydrogen storage systems that provide fuel for a 300-mile range, says Kevin Ott, MPA-MC group leader and national program leader for the Department of Energy’s Hydrogen Storage Center of Excellence. The DOE is aiming for a market penetration of 10 million vehicles by 2025, Ott says.

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Refining Fuel Cell Technology

Scientists in the Laboratory’s fuel cell program are working to develop improved materials to overcome some of the challenges with fuel cells, namely cost, durability and hydrogen storage. A fuel cell uses catalysts to convert hydrogen into electricity. A platinum catalyst creates a reaction that separates the hydrogen into electrons and protons. The protons pass through a membrane (the center of the fuel cell) and combine with oxygen and electrons on the other side of the membrane, producing water. The electrons, which cannot pass through the membrane, flow from the anode to the cathode through an external circuit containing a motor or other electric load, which consumes the power generated by the cell. “The biggest issue with fuel cells is the electrocatalyst,” says Rod Borup, fuel cell program manager at the Laboratory. “We use platinum, and it is expensive. In

order to lower costs, we either have to reduce the amount of platinum, or find a new catalyst.”

Improving Durability

Durability of the fuel cell in a vehicle is another challenge that Lab scientists are addressing. The catalysts—such as platinum—loses reactivity during operation, especially when simulating vehicle operation. The particles grow in size, so you have fewer, larger particles. With bigger particles, you lose the amount of reactivity from the platinum. One way to make up for it is to put in more platinum, which raises costs. Instead, lab scientists are looking for alternative, cheaper catalysts. Not only does the catalyst lose its reactivity, but the membrane can also form pinholes or become thin over time, both of which can degrade performance. The membrane itself is expensive as well, so materials are being developed to lower these costs.

Chemical Hydrogen Storage

In April 2004, a LANL-led collaboration focusing on chemical hydrogen storage was awarded the Chemical Hydrogen Storage Center of Excellence, one of three DOE Hydrogen Storage Centers of Excellence. In 2008, LANL was awarded part of the Hydrogen Storage Engineering Center of Excellence, to develop the engineering to safely and economically store hydrogen on board a vehicle.   “We are focusing on chemical hydrogen storage, which means we are storing the hydrogen in molecules,” says Kevin Ott, Materials Physics Applications-Materials Chemistry group leader and national program leader for the Department of Energy’s Hydrogen Storage Center of Excellence. “Our main focus is on amine borane. It turns out that amine borane can release hydrogen under fairly mild conditions.” The spent fuel must be recycled to meet cost and efficiency targets. "Designing chemically and energy efficient fuel regeneration processes is one of our primary challenges," Ott says. DOE's goals are to have hydrogen storage systems that can provide hydrogen for a 300-mile range, and can allow for complete light vehicle market penetration of 10 million vehicles by 2025. "With this number of vehicles, and the amount of hydrogen that needs to be stored to achieve this, the volumes of storage materials and the scale of the chemical processes required are quite large, and provide a significant challenge,” he says.